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METHOXYCHLOR AS A BLACKFLY LARVICIDE, PERSISTENCE OF ITS RESIDUES IN FISH AND ITS EFFECT ON STREAM ARTHROPODS

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ABSTRACT

Low-level exposures of brook trout indicated that accumulation of mexthoxychlor was generally less that that of DDT. Based on the average accumulation in three brook trout after exposure to methoxychlor, loss of 41.3 per cent of the accumulation occurred within 1 week after the fish were transferred to clean spring water. No residue was detected after 3 months.

Hatchery ponds, stocked with common sunfish and brown bullheads and operated as a closed ecological system, were used to compare the accumulation and elimination of DDT and methoxychlor in the fish and some members of the food chain. Three separate additions of chemical were made at intervals in 1965 to produce calculated concentrations of +0.005 ppm of DDT in one pond and of methoxychlor in the other. Two similar applications were made in 1966. Samples were taken 36 and 118 days after the final addition in 1965 and 63 days afeter the final addition in 1966. No methoxychlor was detectable in any sample in either year. DDT and its metabolites were present in all samples from the DDT-treated pond. Residues in the fish ranged from 1.68 to 9.4 ppm in terms of wet weight in 1965. Residues increased in young-of-the-year sunfish between 36 and 118 days after the final application. Crayfish, snails and dragonfly larvae also contained residues. In 1966 fish from both ponds showed a reduction in fat and oil expressed as percentage of body weight. Those from the DDT pond approached a level indicative of acute starvation, which could be attributed to the effect of the chemical on food organisms. DDT residues were also lower than in 1965.

A laboratory study of the effect of starvation on fats, oils and stored DDT residues was conducted on brown trout. Proportionate reduction of p-pDDT occurred coincident with the metabolism of fats and oils bearing that chemical. However, DDT residues, including DDE, were not reduced proportionately.

Methoxychlor as a blackfly larvicide seems unlikely to produce residues of the magnitude and persistence known to occur when DDT is used. Preliminary studies of methoxychlor preparations applied as blackfly larvicides were made, based on stream bottom sampling. Oil solutions and emulsifiable concentrates were found more effective as larvicides than wettable powder, but they also had greater effect on other arthropods. A 15 per cent solution applied at 1 gallon per flight mile appeared as effective as a 20 per cent solution of DDT at a similar application rate. Based on previously obtained, unpublished data on DDT, the effect of methoxychlor on other stream arthropods appeared to be no greater than that of DDT as formerly used.

DDT has been used both as a blackfly (Simulidae) larvicide and adulticide in the State of New York since 1948 (Jamnback and Collins, 1955). It has also been used for mosquito control. The persistence of the chemical in warmblooded animals, its slow rate of excretion and Federal tolerance limits for meat, milk and produce have limited its use in agricultural regions.

Seasonal blackfly control usually involves two to three larvicidal applications within a period of slightly less than 2 months. This may be supplemented by airplane space spraying or ground fogging or mist-spraying in and around inhabited areas for control of adults and other biting insects. Airplane application is preferred in larvicidal treatment since it provides accurate dosage control, and the better distribution appears to improve the efficiency of treatment. It is effective at dosages much lower than those recommended for hand treatment and avoids excessive rates of application which seem unavoidable or entirely too frequent with that method.

A 20 per cent solution of DDT is dispensed at a rate of 1 U. S. gallon per flight mile covering a swath about 100 feet wide. Streams are crossed at right angles, and swaths are placed on approximately ¼-mile centers. This results in an application rate of approximately 0.1 pound per swath acre (assuming all discharged spray reaches the surface, which is not the case).

DDT accumulation in individual fish with equivalent exposure may be quite variable. Persistence and magnification of the chemical in fish flesh appear well documented. Cope (1961) presented data from streams (open ecosystem) in which residues of DDT and its metabolites were persistent in some fish up to 2 years following a single application. A supposedly untreated stream 30 miles from the area was used as a control, but it was found to have unexplained residues equal in magnitude to about 16 per cent of the collected samples in and below the treatment area. Comparison of May samples in 1958 and 1959 showed an average of 1.53 milligrams per kilogram DDT for the treatment area (nine samples) against 0.36 milligrams per kilogram for the control area (seven samples).

Burdick *et al.* (1964) showed extremely high accumulations of DDT and metabolites in lakes in the course of streams (partly closed systems) where the contributory watershed had been treated for blackfly control. High residues persisted to 1966 despite termination of the use of DDT in some of these watersheds (unpublished data).

Bridges *et al.* (1963) reported the persistence of DDT and metabolites in a small pond (closed system) for an extended period of time after a single application.

Laboratory studies of Gakstatter and Weiss (1967) with fish indi-

cated a rapid drop of C_{14}-labeled DDT for 2 to 3 days after they were transferred to clean water following an initial exposure at 30 micrograms per liter. Graphs presented indicate only small or negligible reductions for the remainder of a 32-day period. The slope would indicate that the residues would likely have persisted for several more months.

In 1964 the use of DDT was prohibited on lands under control of the Conservation Department and located in watersheds containing lake trout, and abandonment was recommended on similarly located private lands. A permit was required for the application of any pesticide on State lands. The economic importance of biting-insect control pointed to the need for substitute chemicals to replace DDT.

Travis (1949) had reported methoxychlor to be an effective blackfly larvicide. Methoxychlor had also been reported to be less toxic to warm-blooded animals and less persistent in tissue storage than DDT. Cheng *et al.* (1958) indicated that, while milk from cattle sprayed with methoxychlor preparations showed residues, these became undetectable 10 days after spraying was discontinued. Olney *et al.* (1962) fed methoxychlor to chickens at concentrations up to 1,000 milligrams per kilogram in the feed. At the higher levels it was present in eggs for the major part of the 81-day feeding period, but it was not detected in eggs from birds at even the highest feeding level 28 days after cessation of feeding. Except in the skin and fat, it dropped rapidly in the tissues after feeding was terminated. After 63 days it was less than 0.05 milligrams per kilogram in the skin and fat.

Hickey (1961) stated that 50 per cent of robins fed DDT for 5 days at 110 milligrams per kilogram died, but no robins fed methoxychlor at 3,750 milligrams per kilogram were killed. No records for field applications were available.

Springer (1957) stated that studies of the U. S. Fish and Wildlife Service showed methoxychlor to be much less toxic to birdlife, but that its toxicity to fish differs little from that of DDT.

A substitute chemical for DDT should have nearly as effective a toxicity to the target organism, but avoid the persistent residues and accumulation through biological magnification known to occur with DDT. No data were found available on residue and chemical accumulation of methoxychlor in fish or other coldblooded animals. While it was suspected that it might be less persistent, this needed experimental verification. A number of studies involving measurement of the accumulation of methoxychlor compared with that of DDT in fishes after exposure to similar concentrations were undertaken. These included both laboratory and pond studies. Particular attention was given to the elimination or accumulation of methoxychlor.

METHODS OF CHEMICAL ANALYSIS

Fish specimens, either fresh or after storage in a deep freezer, were macerated in a Waring blendor and dried by lyophilization. The n-hexane soluble lipids were extracted in a Soxhlet apparatus. Cleanup of the lipid material was accomplished by the use of florisil columns which were eluted with a 6:94 ethyl ether-petroleum ether mixture. All solvents, before use, were redistilled over Al_2O_3 and silica gel in an all-glass apparatus. Eluents were removed by evaporation in an air stream. Determination of pesticide residues was made in an Aerograph 600C gas-liquid chromatograph equipped with an electron capture detector. Instrumental parameters were as follows:

Column	5′ x ⅛″ pyrex
Packing	7.5% G.E. Viscasil 30,000 on 60/80-mesh Chromosorb W.
Column temperature	175° C.
Injector temperature	225° C.
Gas flow	60 milliliters per minute nitrogen

The packing used does not satisfactorily separate DDD and o-pDDT; hence the reported o-pDDT must be assumed to have included DDD (TDE).

PERSISTENCE OF DDT AND METHOXYCHLOR RESIDUES

Both laboratory and pond studies were made concerning the persistence of DDT and methoxychlor as residues in the tissues of fish.

Laboratory Studies

A preliminary laboratory study involved exposing each of four brook trout (*Salvelinus fontinalis*) to 16 liters of a 5-microgram-per-liter (5 ppb) solution of DDT and four others to 16 liters of the same concentration of methoxychlor. Solutions were replaced daily. The data obtained are presented in Tables 1 and 2. The DDT exposure was found to exceed the lethal level for three of the four fish, so it was not possible to follow the original plan to compare two fish from each group with respect to the rate of accumulation and loss during exposure to clean water for 1 week.

A high degree of variability in the percentage of oil and chemical residues makes exact numerical conclusions questionable. Three of the four DDT-treated fish died during exposure, so their average time of exposure was less than that for the two methoxychlor-treated fish that were killed at the end of the exposure period. The loss, 4 days after removal to clean water, of one fish exposed to methoxychlor is believed to have been caused by a metabolic upset. The high residue content

TABLE 1. RESIDUES OF DDT IN BROOK TROUT (FOUR FISH) EXPOSED TO SOLUTION * OF CHEMICAL FOR 7 DAYS

Analyzed after:	Wet weight (grams)	Oil (per cent)	Residue (micrograms per gram)						Average total chemical and metabolites
			In oil		In wet weight				
			DDE	DDT	DDE	o-pDDT	p-pDDT	Total as DDT	
Death in 4 days	23.36	3.99	12.12	59.98	0.484	0.321	2.07	2.931	2.948
Death in 6 days	26.41	1.22	29.35	162.67	0.357	0.303	1.68	2.381	
Death in 7 days	21.61	0.13	179.60	607.40	0.233	0.112	3.16	3.532	
Exposure plus 7 days in clean water	23.73	3.34	17.09	112.18	0.571	0.591	0.68	1.908	..

* Concentration of 0.005 milligrams of methoxychlor per liter; solution changed daily.

Table 2. Residues of Methoxychlor in Brook Trout (four fish) Exposed to Solution * of Chemical for 7 Days

Analyzed after:	Wet weight (grams)	Oil (per cent)	Residue (micrograms per gram)		Average total chemical and metabolites
			In oil	In net weight	
Exposure.....	30.33	2.08	125.4	2.610	1.759
Exposure.....	22.71	0.34	269.9	0.907	
Death after exposure plus 4 days in clean water...	17.63	3.11	142.4	4.440	..
Exposure plus 7 days in clean water...	28.60	3.05	30.5	0.930	..

* Concentration of 0.005 milligrams of methoxychlor per liter; solution changed daily.

could have been the result of an abnormal intake and retention of methoxychlor. On the basis of the mean concentrations at death or termination of exposure, the rate of uptake and storage of DDT and its metabolites was greater than that for methoxychlor. The data are inadequate to afford any conclusion on the comparative rates of elimination.

A second laboratory study was started to evaluate the retention of methoxychlor in brook trout. Six fish were exposed to 0.005-milligrams-per-liter solutions of methoxychlor (three fish to 64 liters of solution) for 2 days, transfered to clean water for 1 week, and then exposed to the same concentration of methoxychlor for 2 more days. During the periods of exposure, the solutions were changed twice daily. Three of these fish were then sacrificed and analyzed immediately, while the other three were held in running water 1 week before analysis. An additional six fish from the same lot were exposed similarly and analyzed after 3 months in running water. The results are summarized in Table 3. A two-stage exposure period was used to provide an opportunity for metabolism, translocation and storage of chemical intake and to prevent development of tissue concentrations which might induce mortality if the intake exceeded the storage rate.

While there was considerable spread in the amount of methoxychlor found in individual fish as milligrams per kilogram of total body weight, there was no abnormality such as that which appeared in one of the fish listed in Table 2. Approximately 41.3 per cent of the average methoxychlor residue present after exposure was eliminated during the week in running water. No residue was found in the fish after 3 months in running water. Short of continued exposure in the environment through

TABLE 3. RESIDUES OF METHOXYCHLOR IN BROOK TROUT (12 FISH) EXPOSED TO SOLUTION * OF CHEMICAL FOR TWO 2-DAY PERIODS A WEEK APART

Fish	Wet weight (grams)	Oil (per cent)	Residue (micrograms per gram)			
			In oil	In wet weight		
				Amount	Average	Reduction following exposure (per cent)
Immediately after exposure						
1	57.57	4.90	15.10	0.74	0.863	xxx
2	51.42	4.78	17.35	0.83		
3	51.21	3.67	27.78	1.02		
After 1 week in running water following exposure						
4	42.04	5.38	5.58	0.30	0.507	41.3
5	49.09	7.11	7.31	0.52		
6	47.45	5.16	13.56	0.70		
After 3 months in running water following exposure						
7	128.39	6.35	§	§	0.0	100.0
8	102.16	7.26	§	§		
9	118.91	7.05	§	§		
10	89.88	7.07	§	§		
11	102.54	6.70	§	§		
12	107.49	7.67	§	§		

* Concentration of 0.005 milligrams of methoxychlor per liter; solution changed twice daily.
§ Not detectable.

inclusion in the food chain, or recycling in lakes and ponds, persistent residues seem no more likely to occur in fishes than in warmblooded animals. Without persistence over extended periods, no effect on reproduction or storage of massive concentrations in the fats and oils would seem possible at non-lethal concentrations.

POND STUDIES

It was recognized that laboratory experiments cannot in any way correspond exactly to field exposure conditions where, in addition to exposure to the original solution, fish may be continually exposed to residues concentrated in the food chain or recycled in the environment. Exposure under generally closed-system conditions, such as would be provided in a pond with no discharge, should provide optimum exposure

Table 4. Summary of the Dates of Treatment and Conditions in the Ponds, the Stocking Done and the Samples Subsequently Taken for Analysis

Treatment*		Fish stocked				Subsequent sampling		
							Nature of sample	
Date	Condition of pond	Date	Species	Number	Size (inches)	Days after treatment	Number	Age
Pond treated with DDT—1965								
July 6	Filamentous algae and some rooted vegetation.	July 8	Bullhead	300	1½–2	36 118	6 0	Adult§ ..
July 22	Most of filamentous algae removed before treatment	July 12	Sunfish†	234	3–5	36	4 206	Adult Young of year
August 19	Same as on July 22					118	52	Young of year
Pond treated with methoxychlor—1965								
July 6	Filamentous algae and some rooted vegetation.	July 8	Bullhead	300	1½–2	36 118	6 0	Adult§ ..
July 22	Most of filamentous algae removed before treatment	July 12	Sunfish†	234	3–5	36	4 154	Adult Young of year
August 19	Same as on July 22					118	1 211	Adult Young of year

Pond treated with DDT—1966								
May 13	Some vegetation and algae	..	Bullhead	0	..	63	1	Adult§
July 20	Abundant vegetation and algae bloom	..	Sunfish	0	..	63	2	Adult
							92	Young of year
							74	I+ fish
Pond treated with methoxychlor—1966								
May 13	Heavy vegetation, some algae	..	Bullhead	0	..	63	3	Adult§
July 20	Same as on May 13	..	Sunfish	0	..	63	3	Adult
							49	Young of year
							30	I+ fish

* The amount of chemical added on each date was calculated to give a concentration of 5 ppb in the pond.
§ Fish from original stocking.
† Spawning observed.

TABLE 5. ANALYSES OF CONTROL FISH AND SAMPLES FROM THE POND TREATED WITH DDT

Species	Age	Days after last treatment	Wet weight (grams)	Oil (per cent)	Residue (micrograms per gram)					
					In oil		In wet weight			
					DDE	DDT	DDE	o-pDDT	p-pDDT	Total as DDT
Controls—1965										
Sunfish	Adult	*	6.88	1.67	16.05	19.36	0.268	0.184	0.137	0.520
Bullhead	Imm.	*	3.51	2.66	3.89	5.98	0.104	0.000	0.159	0.275
		*	3.12	1.10	10.94	10.88	0.120	0.000	0.119	0.253
1965										
Sunfish	0+	36	0.8541§	4.20	28.38	84.64	1.19	1.72	1.84	4.89
		118	0.8306§	2.97	52.42	144.36	1.56	1.80	2.48	6.02
	Adult	36	29.33	4.90	31.27	90.15	1.53	2.99	1.43	6.13
		36	44.77	6.28	19.04	52.62	1.20	1.74	1.56	4.64
		36	48.24	6.49	21.99	79.92	1.43	2.36	2.83	6.78
		36	53.15	5.03	29.96	0.00	1.51	0.00	0.00	1.68
Bullhead	Adult	36	22.01	2.73	48.23	83.01	1.32	1.17	1.09	3.73
		36	20.39	3.14	50.30	81.57	1.58	2.56	0.00	4.32
		36	25.96	2.93	54.40	101.58	1.59	1.30	1.67	4.74
		36	43.19	3.43	49.34	75.36	1.69	1.42	1.16	4.46
		36	44.83	4.55	35.40	79.74	1.61	1.80	1.83	5.43
		36	46.58	2.13	70.56	361.79	1.51	7.28	0.44	9.40

			1966							
Sunfish	0+	63	0.8340§	1.76	19.41	29.53	0.34	0.31	0.21	0.90
	I+	63	3.9827§	1.35	54.90	98.06	0.71	0.91	0.35	2.05
	Adult	63	30.65	0.19	62.69	22.27	0.12	0.018	0.024	0.176
		63	35.56	0.13	21.26	17.51	0.03	0.00	0.023	0.056
Bullhead	Adult	63	96.10	0.50	61.26	30.48	0.30	0.04	0.113	0.488

* Not exposed to treatment.
§ Average for sample (see Table 4).

and retention of the chemical. Two ponds at the Cape Vincent fish hatchery were used. Their volumes were computed, and they were filled to a measured level. In 1965 both were stocked with common sunfish (*Lepomis gibbosus*) and brown bullheads (*Ictalurus nebulosus*). One pond was treated with DDT in acetone to produce a concentration of 5 micrograms per liter (5 ppb) on several dates. The other received similar treatment with methoxychlor. A general summary of conditions in the ponds, dates of treatment, stocking, and samples collected for analysis is presented in Table 4 for the years 1965 and 1966.

While the fish used for stocking the ponds came from areas where DDT was not known to have been used, it is known that in most regions of this country fish cannot be obtained which are entirely free of DDT and its metabolites. For that reason, when the ponds were stocked a few fish were retained as controls for analysis of DDT and its metabolites. The analyses of these fish and of the fish collected in the two ponds after exposure during 1965 and 1966 are presented in Tables 5 and 6.

The extreme reduction in fat and oil content of the fish collected from the DDT-treated pond in 1966, together with their generally lower weight, indicates that a condition of near starvation existed there. It was extremely difficult to obtain adult fish from this pond in 1966. The DDT content of the fish was much lower than in 1965. Although one less treatment was made in 1966 than the year before, this is not believed to explain the variation in DDT content. Starvation would result in mobilization and metabolism of stored fats. If accumulated DDT were metabolized or eliminated at this time, a significant reduction in DDT could be effected. Accordingly, a laboratory study was set up to which 30 brown trout (*Salmo trutta*) were exposed to DDT at a concentration of 2 micrograms per liter for 6 days with the solution being changed daily. At the end of that period 10 fish were killed, frozen in a deep freeze and held for analysis as a single lot to obtain an average figure for stored DDT and metabolites. Another 10 were placed in running spring water and held for 30 days without feeding, except for whatever organisms might have been carried in the spring water. The third group of 10 were held for a similar period but were fed. All lots were then analyzed. Due to the possible loss of moisture in the deep freeze, analyses and computations were based on dry weight rather than wet weight. Analytical and computed data are shown in Table 7.

While p-pDDT appears to have been metabolized at nearly the same rate as fat and oil during starvation, a much smaller amount of the DDT and/or DDE appears to have been excreted. Increased DDT in the fed fish is believed to have been due to the presence of DDT and its metabolites in the food. Though this feed was not analyzed, analyses at other times has indicated DDT to be present. Although the possibility of

TABLE 6. ANALYSES OF SAMPLE FISH FROM THE POND TREATED WITH METHOXYCHLOR

Species	Age	Days after last treatment	Wet weight (grams)	Oil (per cent)	Residue (micrograms per gram)	
					In oil	In wet weight
1965						
Sunfish	0+	36	0.3817*	2.32	§	..
		118	0.4632*	1.72	§	..
	Adult	36	22.84	5.02	§	..
		36	48.98	5.33	§	
		36	43.03	5.10	§	..
		36	42.06	5.37	§	..
		118	49.74	5.70	§	..
Bullhead	Adult	36	26.77	3.37	§	..
		36	35.32	4.24	§	..
		36	101.26	2.24	§	..
		36	29.95	4.32	§	..
		36	33.87	4.68	§	..
		36	29.01	2.92	§	..
1966						
Sunfish	0+	63	1.7527*	2.07	§	..
	I+	63	3.7430*	1.20	§	..
	Adult	63	38.93	1.90	§	..
		63	33.74	1.46	§	..
		63	45.88	2.00	§	..
Bullhead	Adult	63	68.19	3.66	§	..
		63	113.81	1.47	§	..
		63	79.61	2.18	§	..

* Average for sample (see Table 4).
§ Not detectable.

increased excretion with a slower rate of fat and oil metabolism cannot be completely excluded, the failure of the 1966 data to show an accumulation in relation to exposure more nearly comparable to that observed in 1965 was probably due to other causes. It is known that DDT accumulates rapidly on algae and aquatic vegetation, and it is believed that the reduction was due to the greater amounts of these present at the time of treatment in 1966. This would have resulted in lower concentrations and a lessened period of exposure than can be assumed to have occurred in 1965. The evident starvation in this pond was also indicative of a reduction in food organisms, which would have reduced exposure by intake of food which could also have been carrying stored DDT.

Table 7. Effect of Starvation and Feeding on Metabolism and Excretion of DDT in Brown Trout*

Number of fish	Dry weight (grams)	Extracted oil (grams)	Dry weight less oil	Micrograms in oil				Degree of change (in per cent)					
				DDE	o-pDDT	p-pDDT	Total as DDT	Oil	Dry weight less oil	DDE	o-pDDT	p-pDDT	Total as DDT
Fish examined immediately after exposure													
10	5.41	0.7532	4.66	4.59	11.06	40.83	57.02	..	..	..	..	..	..
Fish examined after being held 30 days in running water without food													
10	5.14	0.5269	4.61	13.55	9.69	28.57	53.39	−30.05	−1.07	+195.21	−13.11	−30.03	−6.36
Fish examined after being held 30 days in running water with food													
10	11.58	2.0369	9.54	13.69	11.71	37.78	64.78	+170.43	+104.72	+198.27	+5.55	−7.49	+13.61

* All fish exposed for 6 days to DDT at a concentration of 2 micrograms per liter with the solution being changed daily.

TABLE 8. ANALYSES OF SAMPLES OF FOOD ORGANISMS FROM POND TREATED WITH DDT IN 1965

Organism	Days after last treatment	Weight* (grams	Oil (per cent)	Amount (micrograms per gram)			
				DDE	o-pDDT	p-pDDT	Total as DDT
Crayfish	36	7.74	0.43	0.082	0.000	0.121	0.213
	36	5.62	1.08	0.263	0.000	0.403	0.697
	118	18.65	0.55	0.449	0.122	0.118	0.742
	118	10.78	0.56	0.229	0.000	0.100	0.355
Snails§	118	6.82	0.73	0.037	0.000	0.071	0.112
Dragonfly larvae§	36	0.7947	7.75	0.640	0.000	0.860	1.570

* Wet weight for crayfish and snails; dry weight for dragonfly larvae.
§ Combined lot.

In 1965 a collection of some of the organisms utilized as food in the two ponds was made at the same time that fish were taken from the ponds. Samples of the same species were obtained from both ponds. No detectable methoxychlor was found in any of the samples. Analysis of the organisms taken from the DDT-treated ponds is presented in Table 8.

RELATIVE BEHAVIOR OF DDT AND METHOXYCHLOR

Metcalf (1966) indicated methoxychlor to be comparable to DDT in insecticidal effectiveness, yet to have a lower oral toxicity to the rat and a much more rapid metabolism and elimination from the animal body, apparently because of degradation of the methyl-phenyl-ether linkages to form phenolic derivatives which are eliminated. While this statement is believed to refer primarily to behavior of the chemical in warmblooded animals, this study demonstrated that the same behavior occurs in fishes and even in aquatic insects, snails and crayfish. Loss of 41.3 per cent of the methoxychlor present after a low-level exposure occurred after the experimental fish had been in clean water only 1 week. The complete elimination within a period of less than 36 days in a pond system, where recycling of any persistent chemical could be expected to occur, further supports the conclusion that persistent residues do not occur beyond short periods following exposure. Further, the inability to find methoxychlor in the food chain in as short a period as 36 days indicates it is not likely to accumulate in the ecosystem. The pond studies further indicate DDT to have a greater and more permanent effect on the food organisms. The behavior of methoxychlor is completely different from that of DDT, and it appears much more satisfactory as a larvicide.

EFFECT OF METHOXYCHLOR ON STREAM ARTHROPODS

The relatively short persistence of methoxychlor in fish tissue and in some members of the food web in an ecosystem satisfies only part of the requirements for a satisfactory blackfly larvicide. An effective and satisfactory substitute for DDT should also be nearly as effective on blackfly larvae and produce no greater mortality in other stream arthropods. Jamnback and Frempong-Boadu (1966) reported some exploratory studies which indicate that in the streams studied methoxychlor as a blackfly larvicide had about the same effectiveness as DDT.

Through the cooperation of Dr. Hugo Jamnback of the State Museum Science Service, this Department was able to conduct studies on the effect of experimental applications of methoxychlor to a number of Adirondack streams. The Department's primary interest was in obtaining an estimate of the impact of such treatments on arthropods other than blackflies. Arthropods comprise the major food supply of stream fish.

The procedure, as used in previous studies conducted by the Department (unpublished), involves about nine samples collected through the season in treated streams. A prespray sample is collected prior to each application of larvicide, followed by a postspray collection from 2 to 3 days after the application. Drift collections may be taken during the spray application. A short delay following application is deemed necessary to prevent inclusion of grossly affected and dying insects which might otherwise appear in the postspray samples. Further samplings are taken in July, August and September to evaluate any recovery or persistence of effect beyond the actual spray period. A Surber square-foot sampler is used in collecting the samples, and the procedure is standardized as much as possible. The riffle area chosen for sampling must be of adequate length and uniformity of composition to allow for the collection of 18 samples through the season without reworking any portion of the area. While additional samples would increase accuracy, the number of areas which fulfill even the above requirements are usually limited.

A number of discussions of sampling by the Surber sampler have appeared in the literature. Most of the criticism appears to be based on the assumption that it is necessary to obtain a representative and proportionate sample of all riffle-dwelling organisms. Population density and species composition may vary with depth and distance from shore. A sampling will usually obtain only a portion of the organisms in a vertical 1-foot square of bottom. If the procedure is standardized, it may be assumed to sample a fairly uniform percentage of the organisms. In studies by this Department only the central portion of the riffle is sampled, thus avoiding non-uniformity which would be present if sampling were done at various distances from either shore.

Because of the small number of samplings, infrequently occurring,

abnormally large organisms which could bias the results are not included in the weights or numbers. Samples were placed in white-bottomed pans and picked into 50 per cent alcohol in the field. The organisms were later counted and separated according to size and family. They were weighed from 50 per cent alcohol, blotting off any excess liquid. Simulidae, though counted, were not included in gross weights or numbers.

While a greater number of samples could have been taken in these experimental studies, the same sampling procedure was used as in actual field application in order that the results might be comparable. The effect noted in the samples represents only the change occurring at the particular point, depth and type of bottom. The samples do not represent optimum blackfly habitat which is usually shallower. Neither can they be interpreted as representative of the effect in all areas of the stream.

High Rock Pond Outlet, a tributary to Seventh Lake of the Fulton Chain, was used for experimental applications of two different methoxychlor preparations in 1965. The chemicals were applied by Dr. Jamnback using the quantity which would be discharged to the stream from a single airplane swath. In each case, application was made with a small hand sprayer, using 7 milliliters of solution over a period of 20 minutes. Samples of stream organisms were collected by Department personnel.

The first preparation used was 20 per cent methoxychlor in fuel oil. Prespray and postspray square-foot samples were collected about ½ mile below the point of application. Drift sampling was done somewhat closer, probably about ¼ mile below. A heavy drift of mayflies and stoneflies and a lesser drift of caddis occurred. Blackflies comprised only 8.8 per cent of the drift. The square-foot-sampling area appears to have been located too far below the point of application for satisfactory treatment, since a reduction in Simulidae larvae of only 20 per cent was recorded there. Displacement of organisms was evidenced by the fact that, while the mean weight of those other than Simulidae was reduced 3.8 per cent, the number increased 64.7 per cent. Displaced larger organisms appear to have been replaced by smaller organisms in the drift. This could occur only if it can be assumed that all affected insects in the drift were not actually dying and that a certain number of them recovered and repopulated downstream areas. Table 9 summarizes the average numbers of representatives of each family found resident in the sampling area in the prespray and postspray collections based on two square-foot samples in each case.

The same table also summarizes the results for the application of the second preparation, a 24 per cent methoxychlor emulsifiable concentrate, which was applied to a different portion of the stream. In this experiment, bottom and drift sampling were done about ⅛ mile below the

Table 9. Average Numbers of Representatives of Each Family of Arthropods Recorded in Bottom Samples Taken Following Applications of Methoxychlor in High Rock Pond Outlet in 1965

Order and family	Methoxychlor, 20 per cent in oil, applied June 8*			Methoxychlor, 24 per cent emulsified, applied June 9§		
	Prespray June 7	Postspray June 11	Change (per cent)	Prespray June 9	Postspray June 15	Change (per cent)
Coleoptera						
Elmidae	26	38½	xxx	59	69	xxx
Ephemeroptera						
Baetidae	1	1	xxx	½	1	xxx
Heptageniidae	1½	..		4½	1½	xxx
Trichoptera						
Hydropsychidae	½	1	xxx	4½	2½	xxx
Odontoceridae	..	..	xxx	..	1	xxx
Psychomyiidae	1	..	xxx	..	½	xxx
Limnephilidae	½	..	xxx	1	..	xxx
Rhyacophilidae	..	½	xxx	3½	2½	xxx
Plecoptera						
Nemouridae	3	19½	xxx	56	29	xxx
Pteronarcidae	..	½	xxx	..	½	xxx
Chloroperlidae	..	½	xxx	..	½	xxx
Diptera						
Tipulidae	6½	1½	xxx	3	2	xxx
Rhagionidae	½	..	xxx	..	..	xxx
Tendipedidae	2	6½	xxx	10	16½	xxx
Heleidae	..		xxx	½	..	xxx
Simulidae†	10	8	−20.0	101½	1½	−98.6
Total, except Simulidae						
Number	42½	70	+64.7	142½	126½	−11.9
Weight (grams)	0.1711	0.1643	− 3.8	0.2579	0.1165	−54.9

* Theoretical concentration: 0.0165 milligrams per liter.
§ Theoretical concentration: 0.0198 milligrams per liter.
† Immediately following application of the chemical, Simulidae comprised 8.8 per cent of drift collections for the 20 per cent in oil preparation and 34.7 per cent for the 24 per cent emulsified preparation.

point of application. This was much more effective on blackflies in the bottom area sampled, causing a reduction of 98.6 per cent. The weight of other organisms was reduced 54.9 per cent, and the number 11.9 per cent.

Dr. Jamnback selected Wheeler Brook, also tributary to Seventh Lake, for experimental applications of 3.5 grams of 50 per cent methoxychlor wettable powder, applied with a hand sprayer over a period of 20 minutes. After the first application, Simulidae comprised 88.9 per cent

of the drift collected ½ mile below the point of application. Bottom samples at the same location showed a reduction in Simulidae larvae of 53.8 per cent. For the other organisms, a 10.9 per cent reduction in weight and a 12.3 per cent increase in numbers occurred. Two days after the initial spraying, another treatment was made ⅜ mile downstream. The same sampling area was used, although now it was ⅛ mile below the treatment point. Simulidae constituted 74.6 per cent of the drift. Bottom samples showed a reduction in Simulidae larvae of 31.7 per cent. For the other organisms, both numbers and weight increased to about the same degree, 20.3 per cent and 22.5 per cent, respectively, indicating that the added population was similar to those already present. Table 10 summarizes the average numbers of representatives of each family found in these collections based two square-foot samples in each case.

TABLE 10. AVERAGE NUMBERS OF REPRESENTATIVES OF EACH FAMILY OF ARTHROPODS RECORDED IN BOTTOM SAMPLES TAKEN FOLLOWING APPLICATIONS OF METHOXYCHLOR IN WHEELER BROOK IN 1965

Order and family	First application, June 9*			Second application, June 11*		
	Prespray June 7	Postspray June 11	Change (per cent)	Prespray§ June 11	Postspray June 15	Change (per cent)
Coleoptera						
Elmidae	½	..	xxx	..	..	xxx
Ephemeroptera						
Baetidae	½	..	xxx	..	..	xxx
Heptageniidae	6½	9	xxx	9	7½	xxx
Trichoptera						
Hydropsychidae	½	..	xxx	..	..	xxx
Rhyacophilidae	½	..	xxx	..	½	xxx
Psychomyiidae	½	1½	xxx	1½	..	xxx
Plecoptera						
Nemouridae	12½	10	xxx	10	21	xxx
Diptera						
Tipulidae	..	½	xxx	½	..	xxx
Tendipedidae	9	11	xxx	11	7½	xxx
Simulidae†	112½	52	−53.8	52	35½	−31.7
Total, except Simulidae						
Number	28½	32	+12.3	32	38½	+20.3
Weight (grams)	0.1146	0.1021	−10.9	0.1021	0.1251	+22.5

* Theoretical concentration: 0.0427 milligrams per liter.

§ Same as postspray sample for first application.

† Immediately following application of the chemical, Simulidae comprised 88.9 per cent of drift collections for the first application and 74.6 per cent for the second application.

While the wettable powder appeared to produce less derangment in existing population than did the oil solution and the emulsifiable concentrate, it did not appear on the basis of bottom sampling to be as effective

Table 11. Average Numbers of Representatives of Each Family of Arthropods Recorded in Bottom Samples Taken Following Applications of Methoxychlor by Airplane in South Branch of Crystal Creek in 1965 and 1966

Order and family	Methoxychlor, 20 per cent in fuel oil plus 0.5 per cent Triton X161, applied April 17, 1965*			Methoxychlor, 15 per cent in HAN-121 plus 0.5 per cent Triton X161, applied April 14, 1966§		
	Prespray April 17	Postspray April 19	Change (per cent)	Prespray April 14	Postspray April 18	Change (per cent)
Coleoptera						
Elmidae	3	5	xxx	18	2½	xxx
Ephemerotera						
Baetidae	92½	74½	xxx	53½	45	xxx
Heptageniidae	9	9	xxx	17	4	xxx
Trichoptera						
Hydropsychidae	9	11½	xxx	27	8½	xxx
Glassostomatidae	4½	2	xxx	10½	4	xxx
Rhyacophilidae	2	6	xxx	6	3	xxx
Psychomyiidae	7	1½	xxx	..	..	xxx
Goeridae	½	..	xxx	½	½	xxx
Leptoceridae	1	..	xxx	..	..	xxx
Plecoptera						
Perlidae	1½	3½	xxx	2½	1½	xxx
Perlodidae	1½	2½	xxx	3½	..	xxx
Chloroperlidae	1	..	xxx	..	1	xxx
Diptera						
Tipulidae	8	3½	xxx	7½	6½	xxx
Heleidae	2½	1½	xxx	½	..	xxx
Rhagionidae	..	..	xxx	1	1½	xxx
Tendipedidae	20	4	xxx	11½	2	xxx
Simulidae†	..	..	..	..	..	..
Odonata						
Gomphidae	..	..	xxx	½	..	xxx
Total						
Number	163	124½	−23.6	159½	80	−49.8
Weight (grams)	0.4080	0.5029	+24.2	0.7151	0.4000	−44.1

* Based on swath width of 100 feet and stream cross-section of 16 feet by 10 inches' maximum concentration would have been less than 0.0608 milligrams per liter.

§ On same basis, maximum concentration would have been less than 0.0456 milligrams per liter.

† Although no blackflies were taken in the bottom samples, in drift collections immediately following application of the chemical, Simulidae were present (less than 10 per cent) in 1965 and amounted to 40.1 per cent in 1966.

on the blackfly larvae. It had much less effect on mayflies, stoneflies and caddis.

The South Branch of Crystal Creek below Petries Corners in Lewis County was chosen for studying the effectiveness of airplane application. In 1965 a single swath was applied using 20 per cent methoxychlor in fuel oil with 0.5 per cent of Triton X161 as a dispensing agent. Drift and bottom samples were taken ¾ mile below the swath. While there was an abundance of mayflies and stoneflies in the drift, the proportion of blackfly larvae was less than 10 per cent. It appeared that the sampling point was too far below the point of application for satisfactory treatment. Numbers of other organisms were reduced by 23.6 per cent while their weight increased by 24.2 per cent. It is believed that smaller organisms in the area which were affected were replaced by larger organisms in the drift. In areas closer to the spray swath satisfactory control of blackflies appeared to have been achieved. In 1966 the stream was again used to see if a 15 per cent methoxychlor treatment would give effective control. A preparation of 15 per cent methoxychlor in HAN-121 with 0.5 per cent Triton X161 was applied in two swaths on ¼ mile centers at the rate of 1 gallon per flight mile. The same bottom and drift sampling point was used as in 1965. With two swaths it was ½ mile from the last point of application. Simulidae larvae made up 40.1 per cent of the drift. Numbers of other organisms were reduced 49.8 per cent and weight 44.9 per cent. The data are given in Table 11 and constituted the average of two square-foot samples in each case.

DISCUSSION

The effect of methoxychlor appears to be dependent both on exposure time and temperature. Two airplane swaths will provide double the exposure time of one. For the lower dosages which appear to have been effective in hand applications, interpretation is complicated by the higher stream temperatures then prevailing. Also, previous studies on DDT spraying (unpublished) have indicated a greater effect from second spray applications, presumably due to increased temperatures. A large number of insects are affected and drift through the area, but there is no evidence that all, or most, of these insects later die. After an application of methoxychlor, some of the drifting mayflies, stoneflies and caddis have been held in trays in stream water for periods of up to 4½ hours with no observed mortality. This time is too short for conclusions to be drawn, but it may be indicative. Displacement of a significant number of insects, even without mortality, can have an effect on stream productivity. Some of the sampling variations are large, however they are within the range of those previously found to occur with DDT spraying. On the basis of these preliminary results it would appear that, as well as being

non-residual in fishes and food organisms, applications of methoxychlor as a larvicide will have no greater effect on general productivity than would applications of DDT. Further study with various dosages may reduce the impact below that of the 15 per cent solution presently being used in the field. Further evaluation of field-scale operations involving this 15 per cent solution is planned.

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PRODUCTION OF YOUNG NORTHERN PIKE IN A REGULATED MARSH[1]

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ABSTRACT

From 1964 to 1967 the production and survival of young northern pike were studied in an experimental marsh at Shackelton Point on Oneida Lake. The number of adults entering the marsh was controlled and their fecundity estimated to determine potential egg deposition. The number of eggs hatching was approximated by determining the density of fry per square foot using screen inclosures, and young emigrating from the marsh were trapped and enumerated. Mortality between spawning and hatching was 81 and 84 per cent in 1965 and 1966, respectively, and the loss of young between hatching and emigration was 83 per cent in both years. Migrants over 65 millimeters long were fin clipped. Recoveries during subsequent spawning runs suggested that few pike survived that were less than 65 millimeters long when they left the marsh. Maintenance of northern pike populations in many lakes may depend primarily on producing large juvenile fish in the nursery areas.

Northern pike (*Esox lucius*) spawn during early spring in shallow marshy areas of lakes or in connected sloughs. High water levels in spring and flooding of grassy sloughs are often associated with successful northern pike reproduction. Johnson (1957) found year-class strength of this species to be closely correlated with spring water levels, indicating that survival in the nursery area may regulate population size.

Survival of young northern pike in spawning marshes is generally low. Carbine (1944) reported a survival of 0.07 to 0.44 per cent based on the potential egg deposition by adults compared with the numbers of young that migrated from a marsh at Houghton Lake (Michigan) during three seasons. Estimates of survival from egg to lakeward migrant at Lake George (Minnesota) were variable ranging from 4.62 to 0.08 per cent between 1956 and 1958 (Franklin and Smith, 1963). Estimates for managed spawning marshes also indicate wide annual variation in survival (Williams, 1962).

From 1964 to 1967 the production of young northern pike was studied in a marsh located at Shackelton Point on the south shore of Oneida Lake. The purpose of the investigation was to estimate survival through the early developmental stages and to provide an initial basis for management of northern pike nursery areas in New York State.

The experimental marsh used was created by impounding a temporary stream at a point ¼ mile from Oneida Lake. A water-control structure with a head of 2½ feet above lake level was installed in 1963. The site was first flooded in 1964 and at normal water level the marsh

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occupied 7.3 acres. Approximately 70 per cent of the area was flooded to a depth of less than 2 feet while the maximum was 3½ feet.

Splash boards were placed in the spillway in early March, and the marsh filled within 2 weeks. Runoff from the 400-acre drainage area was adequate to maintain the water level and permit some outflow over the spillway during April and May. During late spring the discharge was usually limited to a 2-inch flow through a 6-inch-wide slot in the top splash board. During periods of low runoff the outlet was closed during the night to conserve water. The water level was gradually lowered beginning in mid-June to maintain some outflow, and the marsh was drained to lake level in July.

Vegetation on the unflooded site in 1963 consisted of mesophytic weeds and grasses with a few cattails (*Typha*) and rushes (*Juncus*) along the stream bed. After temporary flooding in 1964 water plantain (*Alisma triviale*), spike rush (*Eleocharis calva* and *E. obtusa*) and sedges (*Carex* sp.) predominated. By the third season sparse stands of *Typha* and beds of reed canary grass (*Phalaris arundinacea*) had developed. These successional changes in vegetation probably influenced northern pike production, but their effect could not be isolated from that of annual fluctuations in other environmental parameters.

A trap net was set below the spillway to intercept northern pike migrating upstream to spawn. Adults were transferred to the marsh after their length and sex had been recorded. After spawning had taken place and fry were observed, a downstream trap was placed below the spillway to collect young fish. The downstream trap was operated continuously until the marsh was drained in July. All overflow from the marsh was directed through the trap, and the 18-mesh-per-inch screening in the trap was sufficiently small to retain sac fry. Except on May 1, 1964 when high water levels made the trap inoperative and on June 25, 1965 when muskrats damaged the screening, the trap was probably effective in capturing all emigrants. A few adults were recovered in the downstream trap each year, but most adults stocked in the marsh apparently returned to the lake before the trap was installed.

The downstream trap was usually emptied each day, and the young fish were counted, weighed and released at the trap. Sample specimens were preserved in 10 per cent formalin and later measured to determine the growth rate and length distribution of the catch.

After the marsh was drained to lake level in July the remaining pool, which was less than 1 acre in area, was treated with rotenone. Fewer than 50 young pike were observed each year following this treatment, but no attempt was made to estimate the actual number of northern pike remaining in the marsh. A few small yellow perch and sunfish and various species of minnows entered the marsh before the spillway

was closed in March. The numbers present were probably not large enough to affect northern pike production.

SPAWNING

Adult northern pike entered tributary streams while Oneida Lake was ice covered. Ripe males and females were netted at the marsh spillway from April 7 to 11 in 1964, from April 7 to 16 in 1965 and from March 31 to April 3 in 1966. In Chittenango Creek, a larger tributary system, adults were observed as early as March 23 in 1964 and March 27 in 1965.

All adults netted at the spillway in 1964 and 1965 were released in the marsh, and additional pike netted in Chittenango Creek were transferred to the marsh to assure adequate spawning stock. In 1966 the number stocked was purposely reduced to determine the effect of lower egg deposition on production. Fecundity of females was estimated from the regression

$$Y = 4{,}378X - 65{,}720$$

where Y = number of eggs and X = total length in inches. The regression was based on counts of eggs removed from the ovaries of 11 females ranging from 19 to 32 inches long netted during March of 1965 and 1966. Potential egg deposition of stocked females, as estimated from this regression, was 1,100,000 in 1964, 1,281,000 in 1965 and 668,000 in 1966.

ABUNDANCE AND DISTRIBUTION OF EGGS AND FRY

Most females and all males were ripe when netted, and spawning occurred soon after adults were transferred to the marsh. Fry were first observed 8 to 14 days after stocking, and most eggs hatched within the following 4 to 5 days. During the period eggs were hatching in 1965 and 1966, a series of samples were taken to determine the population of eyed eggs and fry.

Combined egg and fry density was estimated by placing an open-end, 16 x 36-inch rectangular screen cage on the bottom. Sweeps through the length of the cage were made with a fine-mesh net to dislodge eggs and fry from the vegetation and place them in suspension. The cage was repeatedly swept with the net until three consecutive sweeps failed to recover any additional eggs or fry. Collection sites were randomly selected, and they were then located in the field by using a grid system.

The numbers of eggs and fry collected at 60 sites sampled in 1965 and at 80 sites sampled in 1966 showed a contagious distribution (Table 1). High densities of eggs probably resulted from localized spawning by individual females and a tendency by adults to select certain areas of the marsh for spawning. The total population of eggs and fry in the marsh, based on the number per square foot in the sampling units, was estimated

Table 1. Frequency Distribution of Northern Pike Eggs and Fry Recovered from Sampling Units at Shackelton Point Marsh *

Number of eggs and fry	Frequency among sampling units	
	1965	1966
0	26	45
1	12	14
2	4	5
3	2	8
4	3	2
5	2	1
6	1	1
7	0	3
8	2	0
9	3	0
10	2	0
11	0	1
12	0	0
13	0	0
14	2	0
15	0	0
16	0	0
17	0	0
18	0	0
19	0	0
20	1	0

* Each sampling unit had an area of 4 square feet.

to be 217,000 on April 24, 1965 and 97,000 on April 22, 1966. A non-parametric estimate of the variance was calculated following methods outlined by Cochran (1963, p. 16). The standard error of the estimated population was 43,700 in 1965 and 18,400 in 1966. These are minimal estimates of the population and its variance because recovery of eggs and fry from the sampling units was probably incomplete.

At 12 sites, after eggs and fry had been collected by the normal procedure of sweeping the sampling unit until three consecutive sweeps with the net failed to recover any additional specimens, an attempt was made to recover any remaining eggs or fry by removing most of the vegetation and agitating the bottom. At these sites 49 eggs and fry were recovered by the first procedure and five more were recovered by the more thorough examination. This suggests that the sampling procedure underestimated egg and fry density by about 10 per cent and that the best estimate of the total number would be 238,000 in 1965 and 107,000 in 1966.

The apparent mortality of eggs between spawning and hatching, based on the potential egg deposition and the estimated number of fry hatched (Table 2), was 81 per cent in 1965 and 84 per cent in 1966. This was a much higher mortality than the 10 to 36 per cent reported by Franklin and Smith (1963). Their estimate, however, was based on the

TABLE 2. POTENTIAL EGG DEPOSITION, ESTIMATED NUMBER OF EGGS HATCHED AND NUMBER OF YOUNG NORTHERN PIKE EMIGRATING FROM SHACKELTON POINT MARSH IN 1964, 1965 AND 1966

Year	Females stocked	Potential egg deposition	Estimated number of fry hatched	Number of emigrants
1964	19	1,100,000	..	45,121
1965	40	1,281,000	239,000	40,543
1966	16	668,000	107,000	18,666

ratio of live to dead eggs collected during incubation. Loss of eggs from predation, or rapid decomposition of dead eggs, would result in an underestimate of mortality using their technique. In the present study 77 per cent of the 321 eggs collected at various times during incubation in 1965 and 1966 were viable, indicating a much lower mortality rate during incubation than that derived by comparing egg deposition and the number of fry hatched.

Eggs were distributed throughout the marsh where the bottom had been covered with vegetation and flooded to a depth of 8 inches or more. Neither the density nor type of vegetation seemed closely correlated with egg deposition. Since the marsh was drained early in the growing season, the type of vegetation could be controlled. In 1964 two ¼-acre plots were plowed and planted to winter wheat in August. By fall a dense stand of wheat about 6 inches high covered the plots. After the area had been flooded in the spring of 1965, egg density on the two prepared areas and on adjacent areas of natural vegetation was measured by sweeping sample units in the manner already described. The highest density of eggs was found on the flooded stands of winter wheat (Table 3). However, when the experiment was repeated in 1966, egg density was found to be higher on undisturbed natural vegetation consisting of sedges (*Carex*), grasses (*Spartina*) and waterplantain (*Alisma*) than on the

TABLE 3. EGG DENSITY ON PLOTS OF WINTER WHEAT AND ADJACENT NATURAL VEGETATION AT SHACKELTON POINT MARSH IN 1965 AND 1966

Year	Type of vegetation	Number of units sampled	Mean number of eggs per unit
1965	Winter wheat	17	4.67
	Natural vegetation	17	0.67
1966	Winter wheat	14	1.36
	Natural vegetation	14	2.57

plots of winter wheat. The conflicting results in two successive years suggest that the type of vegetation was not the most important factor controlling egg distribution.

GROWTH OF YOUNG

Newly hatched fry 7 to 9 millimeters long were first observed on April 17 in 1964, on April 24 in 1965 and on April 17 in 1966. In 1964

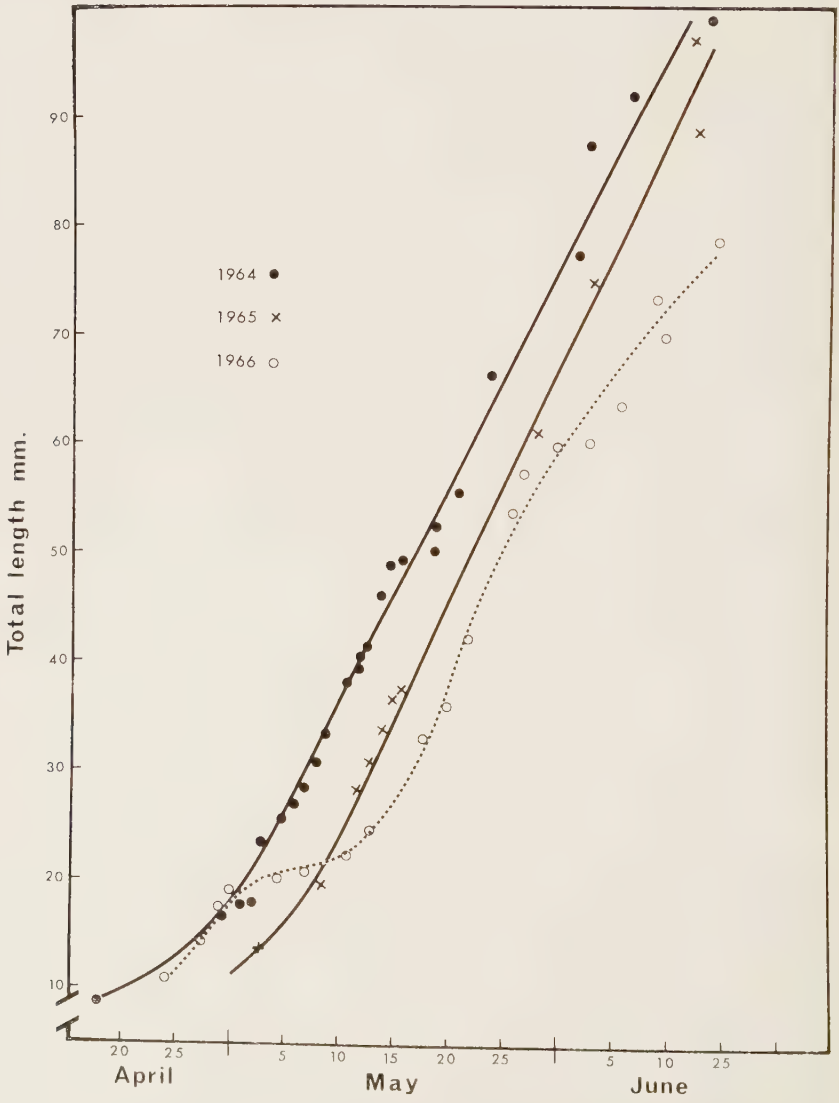

Figure 1. Observed growth of northern pike in Shackelton Point Marsh in 1964, 1965 and 1966.

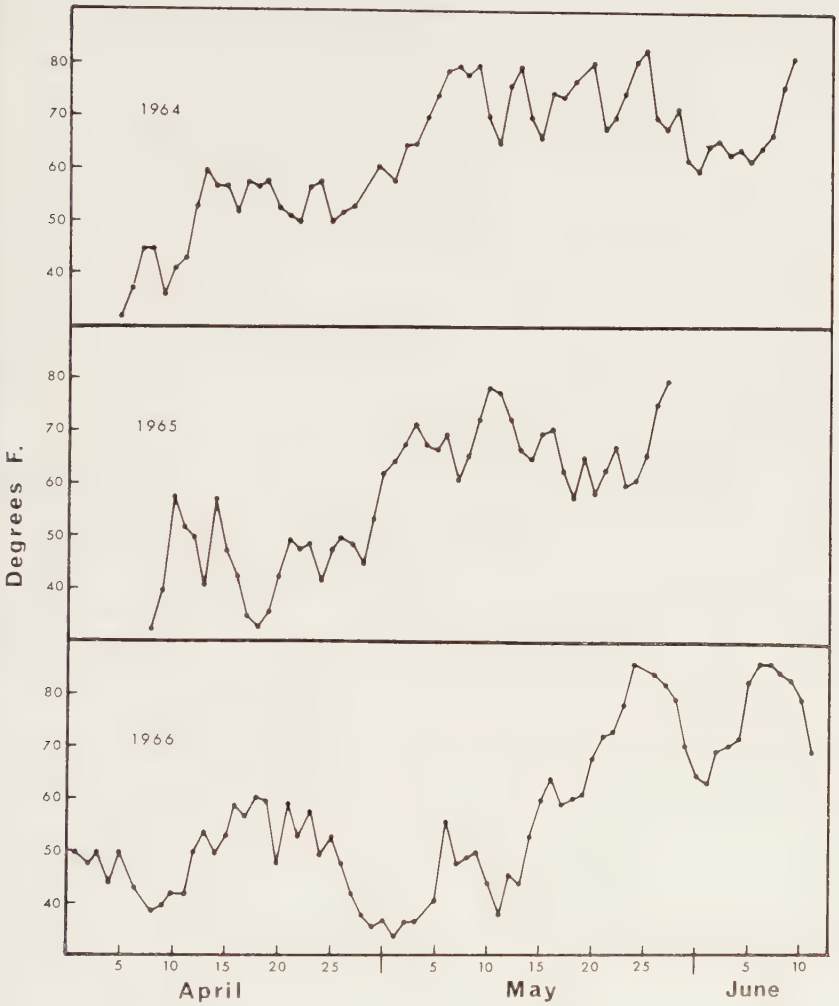

Figure 2. Daily noon temperatures at a depth of 6 inches in Shackelton Point Marsh in 1964, 1965 and 1966.

and 1965, growth in length appeared to be linear after the young had reached a length of 20 millimeters (Figure 1). During May and June in both years, the growth rate was nearly constant and the daily length increment was about 2.4 millimeters. In 1966 a period of relatively slow early growth was followed by rapid growth and then an apparent decline during June. The slow initial growth of young in 1966 may have reflected the unusually low temperatures during early May (Figure 2).

Estimates of growth were based primarily on length measurements of emigrants trapped at the outlet. Emigrants often averaged slightly

longer than young seined in the marsh on the same day, but differences in mean length did not exceed 3 millimeters.

EMIGRATION OF YOUNG

Young ranging in length from 15 to 19 millimeters began moving downstream on April 29 in 1964, on May 7 in 1965 and on April 27 in 1966. Nearly complete counts of emigrants were obtained each year. The largest numbers of young were produced in 1964 and 1965 when between 40 and 46 thousand were trapped (Table 4). In these years peak emigration occurred in early May when the young were less than 30 millimeters long. In 1966 about half as many emigrants were produced, but most of these were over 30 millimeters long.

Daily emigration was strongly influenced by light intensity as has been noted by other workers (Hunt and Carbine, 1951; Franklin and Smith, 1963). On cloudy days heavy emigration started only if the sun appeared, but on clear days emigration was concentrated in the early morning hours. Few, if any, fish moved downstream at night. Exceptionally heavy emigration usually occurred on a clear day following a period of overcast skies. However, when there were several consecutive clear days, emigration did not remain at a high level but declined after the first day. These observations tend to confirm Franklin and Smith's

Table 4. Emigration of Young Northern Pike from Shackelton Point Marsh in 1964, 1965 and 1966

Date	Number trapped at outlet		
	1964	1965	1966
April 25–30	223	..	2,473
May 1– 5	18,262	..	1,624
6–10	12,402	4,007	1,205
11–15	6,187	32,234	1,550
16–20	6,134	3,654	773
21–25	649	272	1,557
26–31	4	164	4,208
June 1– 5	312	45	2,726
6–10	719	11	1,415
11–15	229	19	372
16–20	..	85	119
21–25	..	12	127
26–30	..	5	264
July 1– 5	..	30	140
6–10	..	5	113
Total	45,121	40,543	18,666

opinion that periods of low illumination may delay emigration for several days, but that factors other than illumination probably determine the number of young ready to migrate on a particular day.

Young northern pike seemed to locate the outlet by swimming parallel to shore until they detected the outlet current. On clear days a portion of the population was always observed swimming at the surface near shore. Individual fish moved consistently clockwise or counterclockwise around the periphery of the marsh. Those which were kept under observation for several hundred feet were never observed to reverse direction although they would often dart right or left to avoid fish moving in the opposite direction. As the fish approached within a few feet of the outlet, some swam or drifted toward it while others swam vigorously against the outlet current and continued to move parallel to shore but away from the outlet.

Increasing the volume of water flowing over the spillway did not seem to stimulate migration. The effect of flow was tested by counting the number of young passing over the spillway and the number which bypassed the outlet during a half-hour period when the flow was limited to a 2-inch-deep discharge through the 6-inch-wide slot in the spillway. The flow was then increased to a 6-inch-deep discharge through the slot, and additional counts were made. The proportion of migrants to nonmigrants which passed the outlet remained about the same in several trials on four days during 1966.

Neither variations in light intensity nor fluctuations in outflow would explain the differences observed in the rate of migration from the marsh for the three years of study. During the first 20 days after emigration started, 82, 99, and 37 per cent of the young left the marsh in 1964, 1965 and 1966, respectively. Franklin and Smith (1963) observed similar variation in rate of emigration, and the largest number of migrants was produced in a year when most young emigrated before attaining a length of 35 millimeters.

TABLE 5. SIZE DISTRIBUTION OF YOUNG NORTHERN PIKE PRODUCED IN SHACKELTON POINT MARSH AND TOTAL WEIGHT OF MIGRANTS

Year	Length class (millimeters)				Total weight (pounds)
	17–24	25–49	50–74	75 and over	
1964	13,432	25,781	4,520	1,388	49.4
1965	4,482	35,000	769	292	23.5
1966	6,059	3,697	7,588	1,322	44.2

The number of emigrants was lower in 1966 than in 1964, but the weight of migrants was similar (Table 5). A total of 49.4 pounds of young pike were taken in the outlet trap in 1964 compared with 44.2 pounds in 1966. The yield was much lower in 1965 when only 23.5 pounds were produced. A severe drought in the spring of 1965 resulted in limited runoff and a very restricted flow of water through the spillway. This apparently prevented the return of some adults to the lake. Four adults were taken in the outlet trap in June and eight were recovered when the marsh was drained. Predation by these adults may have substantially reduced production of large fingerlings. In contrast, all brood stock had returned to the lake by early May in 1964 and 1966.

POST-MIGRATION SURVIVAL

Migrants which were over 65 millimeters (approximately 2.5 inches) long were marked by removing the right ventral fin in 1964 and 1966 and the left ventral in 1965. Although only 1,121 were marked in 1964 and 296 in 1965, a significant number were recovered (Table 6). Considering the large area of Oneida Lake (50,000 acres) and the small number of pike marked, the high proportion of marked fish in the catch at the marsh suggests that young either return to a home area to spawn or remain near the stream outlet until they mature. A much lower proportion of marked fish was found among samples of northern pike examined in other areas. At Scriba Creek, which enters the lake 7 miles from the outlet of the experimental marsh, 10 adults were taken in 1965 of which one male and one female were fish marked in 1964, while in 1966 only three fish in a sample of 100 were fin clipped. None of the 39 northern pike collected during 1965 in Chittenango Creek, located 3 miles from the marsh, was marked.

Table 6. Number of Young Northern Pike Fin Clipped Each Year from 1964 to 1966 and Number of Marked Fish Recaptured in the 1965, 1966 and 1967 Spawning Runs at Shackelton Point Marsh

Year released	Number fin clipped *	Number recaptured					
		1965		1966		1967	
		Examined	Marked	Examined	Marked	Examined	Marked
1964	1,121	80	24	82	27	88	7
1965	296	..	..	82	12	88	12
1966	7,062	..	..	..	..	88	32

* Right ventral fin removed in 1964 and 1966, left ventral in 1965.

DISCUSSION

Management of spawning marshes is a well established technique for increasing stocks of northern pike (Laycock, 1966). Such management in Minnesota has been discussed by Franklin and Smith (1963) and their recommendations appear equally applicable to marshes in New York.

Maintenance of northern pike populations in many lakes may depend primarily on producing large juvenile fish in the nursery areas. Franklin and Smith (1963) compared the number of young entering Lake George from a spawning marsh with the year-class abundance at age I+ and concluded that the strength of any year class was largely a function of the number of large juvenile fish (over 35 millimeters) produced. In Oneida Lake there is similar evidence that the size of young at the time of migration may determine their subsequent survival.

Although only 1,121 of 45,121 migrants in 1964 were fin-clipped, 24 of 30 age I (1964 year class) adults collected below the marsh in 1965 and 27 of 37 age II fish netted in 1966 were marked. Similarly 12 of 18 age I pike (1965 year class) caught in 1966 and 12 of 26 age II pike collected at the marsh in 1967 were fin clipped. Assuming that large and small juveniles are equally likely to return to the marsh at maturity, the high proportion of marked fish in the spawning run suggests that few emigrants less than 65 milimeters long (minimum size marked) survived. An alternative explanation is that small early emigrants disperse after reaching the lake, while late emigrants remain near the outlet of the marsh and therefore are more likely to enter the same stream to spawn. However, dispersal from the Shackelton Point area is likely to be balanced by recruitment from other spawning areas, and it seems unlikely that differences in behavior of early and late emigrants would explain the high proportion of marked fish in the 1964 to 1966 spawning runs

The highest yield of large juveniles was attained in 1966. In that year runoff during June permitted holding normal water levels in the marsh for 2 weeks longer than in 1964 and 1965 when rainfall was below normal. This enabled fish to remain in the marsh for an extended period and contributed to the high production of large juveniles. Greater inflow of nutrient-rich water may have also increased the productivity of the marsh, providing favorable conditions for the growth of young pike.

Rapid emigration of small pike occurred in early May of 1964 and 1965 when egg deposition was high, but in 1966, when egg deposition was lower, most young emigrated in late May and early June (Table 4). Density of young at the time of hatching was not determined in 1964, but population estimates indicated that fry were twice as abundant in 1965 as in 1966 when a small proportion of the population emigrated early. Competition for food or other population stress may possibly induce fish

to emigrate soon after attaining a length of 20 millimeters when the initial population density is high. It is reasonable to suspect that northern pike which spawn in an environment where large fluctuations in spawning success are likely may have developed a mechanism to adjust the population density to the food supply and thus minimize cannibalism.

Survival of young was 17 per cent in both 1965 and 1966 based on the estimated number of fry at the time of hatching and total number of lakeward migrants trapped. Since young remained in the marsh an average of 19 days in 1965 compared with 35 days in 1966, daily mortality rates were considerably higher in 1965 than in 1966. The presence of adult pike in the marsh may have increased mortality of young in 1965, or the higher density of young may have resulted in increased cannibalism.

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EFFECTS OF SOIL FERTILIZATION ON THE CONCENTRATION OF CRUDE PROTEIN IN WITCHHOBBLE BROWSE[1]

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ABSTRACT

Effects of soil fertilization on the concentration of crude protein in witchhobble browse were measured using a 2 X 2 X 3 factorial design with (1) two sites, (2) limed and unlimed series, and (3) no fertilizer, a nitrogen fertilizer, and a mixed fertilizer. Plants were measured and browse was collected for analysis after the first growing season following treatment. Nitrogen fertilizer caused an increase in the concentration of crude protein in the browse on the unlimed plots, but not on the limed plots. Liming appeared to stimulate an increased use of nitrogen by soil microorganisms. Most of the additional protein in browse from the unlimed, nitrogen-fertilized plots occurred in the stem-portions of the browse; little if any, occurred in the buds. Mixed fertilizer, supplying nitrogen, phosphorus, potassium, magnesium and sulfur, affected protein levels in the same manner as did nitrogen fertilizer. However, mixed fertilizer stimulated growth of the plants and caused added production of browse, probably by lessening a phosphorus deficiency in the soil.

Protein is considered an especially important component in the diet of deer. It has special roles in growth, reproduction and resistance to disease. In addition, concentration of protein in the diet may limit the digestibility of other components in ruminant foods (Williams *et al.*, 1953). This experiment was designed to explore the possibility that adding fertilizer to the soil might produce a significant increase in the amount of protein in the browse of witchhobble (*Viburnum alnifolium*), an important winter food of deer (*Odocoileus virginiana*) in the Adirondack region.

METHODS

The experiment was conducted during 1963 and 1964 near Newcomb on the Huntington Wildlife Forest, a property of the State University of New York College of Forestry. Two sites, Fishing Brook and Deer Creek, were selected for duplicate tests. Although 4 miles apart, both were within the spruce flat-mixed wood habitat as defined by Braun (1950). The Fishing Brook site had a discontinuous tree canopy, owing to recent experimental poisoning of trees, and was seldom used by wintering deer. Witchhobble plants in this area ranged from 2.5 to 5 feet tall. In contrast, the Deer Creek site was much more shaded and in an area

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where deer concentrated during winter. Witchhobble plants there seldom exceeded 1.5 feet in height because of intensive annual browsing by deer.

At each site six clumps of witchhobble were selected for study, and a plot 15 feet square was established within each clump. A small, temporary deer exclosure was erected within each plot at Deer Creek.

Preliminary tests of soil acidity within the test plots were made by field colorimetric methods on June 3, 1963. Post-treatment soil samples were collected on November 16, 1963, approximately 5 months after application of fertilizer. For the latter, undecayed litter was collected from 3 square feet of surface in each plot, and the top 2 inches of fermenting and humified material, under the litter, were collected from 1 square foot in each plot. All soil samples were analyzed in the soils laboratory of the State University College of Forestry at Syracuse University.

At Fishing Brook four plants on each of the six plots were selected for studying the effect of fertilizer on growth. These were marked with metal tags, measured and described graphically on April 27, 1963. The plants on five of the plots were reexamined on September 5 after the 1963 growing season. (At one plot all the metal tags had disappeared from the plants, hence it could not be reexamined.) The length of new growth on marked twigs, all of which had been unbranched leaders with single terminal buds when marked, was recorded. In some cases, new growth comprised the sum of the lengths of two or three new branchlets which had developed from marked twigs.

The effects of fertilizers on the protein content of witchhobble browse were studied at both Fishing Brook and Deer Creek. The same treatments (Table 1) were used at each site, specific plots being selected at random. The treatments were designed to test the independent and

Table 1. Soil Treatments Applied on Six Plots at Each of the Two Sites

Treatment	Rate of application per acre
Unlimed plots	
Untreated (control)	None
Nitrogen fertilizer	600 pounds ammonium nitrate
Mixed fertilizer	2,000 pounds 10–10–10*
	500 pounds epsom salts
Limed plots	
Lime only (control)	6 tons commercial lime§
Lime and nitrogen fertilizer	Lime and fertilizer rates combined
Lime and mixed fertilizer	Lime and fertilizer rates combined

* GLF Super Plant Food (potential acidity equivalent: 500 pounds $CaCO_3$ per ton).
§ From Lee Lime Corp., Lee, Mass. (MgO: 25 per cent; CaO: 35 per cent; CaO equivalent: 70 per cent).

interacting effects, on levels of crude protein in the browse, of (1) an application of lime, (2) an application of nitrogen and (3) an application of nitrogen with phosphorus, potassium, magnesium and sulfur. They were applied between June 4 and 18 in 1963. Care was exercised in getting the fertilizers onto the litter surface and in keeping them off the plants.

Browse was collected from the plots on the following dates: November 16 in 1963 and January 4, February 15 and March 21 in 1964. One piece of browse was collected from each plot on each date, except that one extra piece was collected from each plot at Deer Creek in January and one extra piece was collected from each plot at Fishing Brook in February. In all, five pieces were collected from each plot. There was no significant relationship between protein levels in these pieces of browse and the date of collection (Bailey, 1967b).

Pieces of browse, collected from prominent twigs in the tops of plant crowns, were clipped 1 inch behind the bases of their terminal buds. Twigs bearing flower buds were not used. After drying at 65° C., the bud and stem from each piece were separated and analyzed for their nitrogen content by the Kjeldahl procedure (Wilde and Voigt, 1959). Crude-protein concentration was expressed as 6.25 times the concentration of nitrogen on an ovendry-weight basis.

Crude-protein concentrations were obtained for the bud- and stem-portions of each piece of browse. A weighted average of these concentrations was used to determine the concentration of crude protein in each whole piece of browse. These data were analyzed using a square-root transformation and analysis of variance procedures for factorial experiments (Steel and Torrie, 1960).

RESULTS

Data are presented for the effects of the treatments on the soils as well as on the witchhobble browse at the two experimental sites.

Soils

Addition of lime to the soil caused an increase in the pH of humus material. Pretreatment measurements ranged from 3.8 to 4.0. Five months after treatment, they ranged from 5.3 to 6.9 on the six limed plots. In contrast, on the untreated control plots they remained below 4.0, and on the unlimed, fertilized plots they ranged between 3.7 and 4.6.

The results of chemical analyses of the post-treatment samples of litter and humus from these plots have been recorded elsewhere (Bailey, 1966). In general, these analyses indicated that applications of lime and fertilizer altered the availability of nutrients on the test plots during the first summer after application. In particular, average concentrations of

exchangeable calcium and of exchangeable magnesium in the humus on the six unlimed plots were 0.49 and 0.19 per cent of ovendry weight, respectively; whereas on the six limed plots these concentrations averaged 2.25 and 1.10 per cent, respectively. Available phosphorus in the humus on the eight plots which had not received mixed fertilizer averaged 0.10 per cent of ovendry weight; whereas on the four plots which had received mixed fertilizer these concentrations averaged 0.19 per cent.

Plant Growth

Witchhobble plants on the plots that received mixed fertilizer exhibited the best growth in 1963 (Table 2). The average linear growth per marked twig was greatest on these two plots, although differences among treatments were not statistically significant. The average propor-

Table 2. Effects of Fertilizers on the Growth of Witchhobble Twigs at the Fishing Brook Site

Fertilizer treatment	Marked twigs		
	Number	Average linear growth (centimeters)	Percentage developing more than one branchlet
With lime			
Control	20	7.2	25
Nitrogen fertilizer	26	5.8	15
Mixed fertilizer	29	8.8	55
Without lime*			
Nitrogen fertilizer	23	7.8	17
Mixed fertilizer	20	15.0	65

* Data were not obtained for the plot that received neither lime nor fertilizer, due to loss of identification of the sample plants (see text).

tion of marked twigs (unbranched leaders when marked) that developed into more than one branchlet was also greatest on these plots, and the difference was statistically significant. On the plots that received mixed fertilizer, 59 per cent (confidence limits: 44 to 73 per cent, $P<.05$) of 49 marked twigs developed into more than one branchlet, while on the other plots this proportion was only 19 per cent (confidence limits: 10 to 30 per cent, $P<.05$) of 69 marked twigs.

Crude Protein in Browse

There was a pronounced difference between the browse samples collected at the two sites, those from Deer Creek having consistently

TABLE 3. MEAN CONCENTRATION OF CRUDE PROTEIN (PERCENTAGE OF OVENDRY WEIGHT) FOR VARIOUS SAMPLES OF WITCHHOBBLE BROWSE AND RELATED ANALYSIS OF VARIANCE

Sample	Per cent
All plots at both sites	7.20
Main treatment effects	
All plots at Fishing Brook	6.76
All plots at Deer Creek	7.64
All limed plots	7.06
All unlimed plots	7.33
All plots treated with nitrogen fertilizer	7.37
All plots treated with mixed fertilizer	7.31
Plots not fertilized (limed and unlimed)	6.91

Analysis of variance (using square-root transformation)

Source	Degrees of freedom	Variance	*F*	
			Value	Reference value*
Treatment	11	0.0545	8.65	2.70 (0.01)
Site	1	0.3969	63.00	7.31 (0.01)
Lime	1	0.0346	5.49	4.04 (0.05)
Fertilizer	2	0.0448	7.11	5.08 (0.01)
Site—lime	1	0.0008	0.13	
Site—fertilizer	2	0.0070	1.11	
Lime—fertilizer	2	0.0316	5.02	3.19 (0.05)
Third-order interaction	2	0.0001	0.02	
Error	48	0.0063		
Total	59			

* Figures in parentheses represent the level of probability for the corresponding reference value.

higher levels of protein than those from Fishing Brook (Table 3). Results of another experiment (Bailey, 1967c) indicate that this difference was related to dissimilarities between the tree-crown densities, the intensities of deer browsing and the quantities of witchhobble browse on the two areas. Plots at Fishing Brook had greater quantities of browse with lower concentrations of crude protein, while plots at Deer Creek had less browse with higher concentrations of crude protein.

Significant differences among crude-protein levels in the browse, due to liming and to fertilizing, were indicated (Table 3), but the significant lime-fertilizer interaction necessitated examining the simple effects within this interaction. Figure 1 illustrates that significant increases in protein concentration were associated with applications of both nitrogen fertilizer

and mixed fertilizer, so long as the soil was not limed. Liming nullified these effects of the fertilizers.

Crude Protein in Buds

Buds of witchhobble from Deer Creek had higher average concentrations of crude protein than did buds from Fishing Brook (Table 4), reflecting the findings with respect to the browse as a whole. There was a significant difference between crude-protein levels in buds from the limed and unlimed plots, but the significant third-order interaction indicated that the effects of liming were not consistent. Auxiliary analyses of variance (Bailey, 1966) indicated that (1) application of lime reduced the protein level in the buds when applied with mixed fertilizer at Deer

Table 4. Mean Concentration of Crude Protein (percentage of ovendry weight) for Various Samples of the Bud-portion of Witchhobble Browse and Related Analysis of Variance

Sample	Per cent
All plots at both sites	7.90
Main treatment effects	
All plots at Fishing Brook	7.58
All plots at Deer Creek	8.21
All limed plots	7.76
All unlimed plots	8.03
All plots treated with nitrogen fertilizer	8.09
All plots treated with mixed fertilizer	7.77
Plots not fertilized (limed and unlimed)	7.83

Analysis of variance (using square-root transformation)

Source	Degrees of freedom	Variance	*F*	
			Value	Reference value*
Treatment	11	0.0353	4.41	2.70 (0.01)
Site	1	0.1904	23.80	7.20 (0.01)
Lime	1	0.0336	4.20	4.04 (0.05)
Fertilizer	2	0.0176	2.20	
Site—lime	1	0.0154	1.92	
Site—fertilizer	2	0.0170	2.12	
Lime—fertilizer	2	0.0066	0.82	
Third-order interaction	2	0.0332	4.15	3.20 (0.05)
Error	48	0.0080		
Total	59			

* Figures in parentheses represent the level of probability for the corresponding reference value.

Creek and (2) a significant increase in protein level in buds was associated with nitrogen fertilization on an unlimed plot at Fishing Brook. Other single-degree-of-freedom comparisons involving simple effects of liming and fertilizing were not statistically significant.

Concentrations of crude protein in the buds showed little variation due to treatment effects. Treatment means for the 12 plots varied from 7.16 to 8.49 per cent based on ovendry weight, the range being only 17 per cent of the average concentration of crude protein (7.90 per cent) in buds for the entire experiment.

CRUDE PROTEIN IN STEM-PORTIONS OF BROWSE

Stem-portions of witchhobble browse from Deer Creek had higher

TABLE 5. MEAN CONCENTRATION OF CRUDE PROTEIN (PERCENTAGE OF OVENDRY WEIGHT) FOR VARIOUS SAMPLES OF THE STEM-PORTION OF WITCHHOBBLE BROWSE AND RELATED ANALYSIS OF VARIANCE

Sample	Per cent
All plots at both sites	6.25
Main treatment effects	
All plots at Fishing Brook	5.75
All plots at Deer Creek	6.75
All limed plots	6.15
All unlimed plots	6.36
All plots treated with nitrogen fertilizer	6.44
All plots treated with mixed fertilizer	6.69
Plots not fertilized (limed and unlimed)	5.62

Analysis of variance (using square-root transformation)

Source	Degrees of freedom	Variance	*F*	
			Value	Reference value *
Treatment	11	0.1466	12.02	2.70 (0.01)
Site	1	0.5960	48.85	7.20 (0.01)
Lime	1	0.0188	1.54	
Fertilizer	2	0.2564	21.02	5.08 (0.01)
Site—lime	1	0.0021	0.17	
Site—fertilizer	2	0.0454	3.72	3.20 (0.05)
Lime—fertilizer	2	0.1519	12.45	5.08 (0.01)
Third-order interaction	2	0.0445	3.65	3.20 (0.05)
Error	48	0.0122		
Total	59			

* Figures in parentheses represent the level of probability for the corresponding reference value.

Table 6. Summary of Simple Effects of Fertilizing and Liming on the Concentration of Crude Protein in the Stem-portions of Witchhobble Browse at the Two Sites

Comparison	Difference in concentration* (percentage of ovendry weight)	
	Deer Creek	Fishing Brook
Lime vs. no lime		
Plots with no fertilizer (control)	+0.89	n.s.
Plots with nitrogen fertilizer	−1.55	n.s.
Plots with mixed fertilizer	n.s.	−0.81
Nitrogen fertilizer vs. no fertilizer		
Plots with lime	n.s.	n.s.
Plots without lime	+2.20	+1.20
Mixed fertilizer vs. no fertilizer		
Plots with lime	n.s.	+0.71
Plots without lime	+1.11	+2.07

* Figures given are all significant at 5 per cent level of probability; n.s. = not significant.

concentrations of crude protein than did those from Fishing Brook (Table 5), also reflecting the findings already noted. Highly significant differences were associated with applications of nitrogen fertilizer and mixed fertilizer. However, significant interactions were also indicated, necessitating auxiliary analyses of variance for comparisons at the tertiary level of treatment effects. These analyses (Bailey, 1966) indicated significant effects of liming and of fertilizing on crude-protein levels in the stem-portions as summarized in Table 6. In general, both nitrogen fertilizer and mixed fertilizer resulted in increased levels of protein in witchhobble stems, especially if lime was not applied. An application of lime without additional fertilizer increased protein levels in the stems of browse at Deer Creek but not at Fishing Brook.

Concentration of crude protein in the stem-portions showed much variation due to treatment effects. Treatment means from the 12 plots varied from 4.79 to 7.93 per cent based on ovendry weight, the range being 50 per cent of the average concentration of crude protein (6.25 per cent) in stem portions for the entire experiment.

DISCUSSION

Nitrogen fertilizers can cause increased concentrations of crude protein in witchhobble browse. Unlimed plots which received 600 pounds of ammonium nitrate per acre produced browse with a protein concentration of 7.72 per cent, whereas on untreated control plots the concentration was 6.82 per cent (Figure 1). The indicated improvement (13

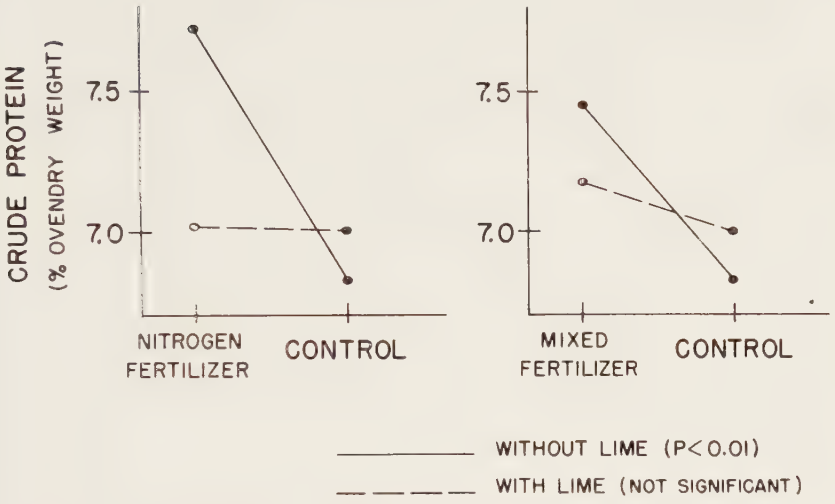

Figure 1. Interacting effects of nitrogen-supplying fertilizers and lime upon concentration of crude protein in witchhobble browse.

per cent) illustrates the potential for managing browse quality with nitrogen fertilizer. However, it is not known whether a 13 per cent increase in protein in the winter diet of deer in the Adirondacks would result in important changes in overwinter survival, reproductive success or herd productivity.

Perhaps all the additional protein in witchhobble browse from the nitrogen-fertilized plots occurred in the stem-portions of the browse. There was no consistent tendency for the buds from the nitrogen-fertilized plots to contain higher concentrations of crude protein than occurred in the buds from the unfertilized plots (Table 4). It appears that the chemical composition of the witchhobble bud is more rigidly controlled by genetic factors, whereas that of the stem can be influenced to a greater degree by site factors such as the availability of nutrients in the soil. In this experiment, protein levels in the stem-portions exhibited greater variation due to treatment effects than did those in the buds. Similarly, Gagnon *et al.* (1958) found no site-related differences among the chemical compositions of the leaves of forest ground-flora plants. In contrast to leaves and buds, woody stems have a nutrient-storage function (Murneek, 1930; Kramer and Kozlowski, 1960), which probably explains their susceptibility to influence by soil fertilization.

Application of mixed fertilizer, supplying not only nitrogen but also phosphorus, potassium, magnesium and sulfur, did not produce witchhobble browse with higher levels of protein than did the application of nitrogen fertilizer alone.

Application of lime to the soil inhibited the effectiveness of nitrogen

fertilizer in improving protein levels in witchhobble browse (Figure 1). Liming caused an increase in humus pH and appeared to accelerate the rate of litter decay on the plots. It is suggested that reduced soil acidity stimulated a greater utilization of nitrogen by soil microorganisms and that the resulting competition for nitrogen inhibited the nitrogen uptake by witchhobble.

It was not a primary objective of this study to measure the effect of fertilizers on the quantity of witchhobble browse. Nevertheless, the meager data in Table 2 are stimulating. Pronounced responses in vegetative growth following phosphorus fertilization on the Huntington Forest have been recorded (Webb and Patric, 1961), and it seems that the better growth of witchhobble on plots receiving mixed fertilizer in the present study can be attributed to an increased availability of phosphorus in the soil. Deer browse in general on this tract is known to be low in phosphorus (Bailey, 1967a.) These findings emphasize the need for additional study of the effect of phosphorus fertilizer on the quantity and quality of deer browse in the Adirondack region.

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THE SPORT FISHERIES FOR SCUP IN THE INSHORE WATERS OF EASTERN LONG ISLAND[1]

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New York State Conservation Department

ABSTRACT

The sport fisheries for scup in the inshore waters of eastern Long Island were studied between May 1 and November 30 from 1964 through 1966. Anglers using rowboats (based primarily in the Peconic Bays) and open boats (based primarily at Montauk Harbor) were heavily dependent upon scup. Together, these facilities accounted for two-thirds, or more, of all scup anglers and over two-thirds of all scup caught. The rowboat anglers had their highest catches and catches per effort in May. The open boat anglers had their greatest success from midsummer to early fall. Differences between these and other sport fisheries for scup, as well as seasonal fluctuations in scup abundance, are discussed. For rowboat anglers in the Peconic Bays the largest fish were caught in May, and after that the size declined. There was also an indication of a missing year class that apparently caused declines in the sport fisheries in the summer of 1966. The possible effect of this missing year class upon the commercial landings of scup is noted.

This study was undertaken to determine the magnitude of the sport fishery for scup (*Stenotomus chrysops*) and the nature of the catch in the inshore waters of eastern Long Island. The area covered comprised Great Peconic, Little Peconic and Gardiners Bays together with the inshore waters of Long Island Sound within the bounds of a line extending from Horton Point northeasterly to the vicinity of the Gull Islands, thence southeasterly through Cerberus Shoal to a point northeast of Montauk Point, thence southerly to Great Eastern Rock and thence westerly to the southern shore of Montauk Point (Figure 1). However, surf fishing from the inlet of Montauk Harbor to the limit of the study area south of Montauk Point was not included.

Field work was done between May 1 and November 30 each year from 1964 to 1966. Data concerning the type of fishing facility used, size of party, time fished, catch of all fish and catch of scup were obtained by personal interview from 18,078 anglers who fished during the daytime. Four hours was considered the minimum for an angler trip, and anglers who had fished less than that time were not recorded. Also, 4,824 scup taken by rowboat anglers in the Peconic Bays were weighed to the nearest 25 grams on an Ohaus spring scale (model 8004) and measured to the nearest 5 millimeters in fork length.

Aerial censuses were made during the same time period. There were 84 flights (28 each year) randomly distributed through each season on weekdays and weekend days (holidays were considered as weekend days). Aerial observation provided instantaneous counts of bank and pier anglers

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[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project F-15-R.

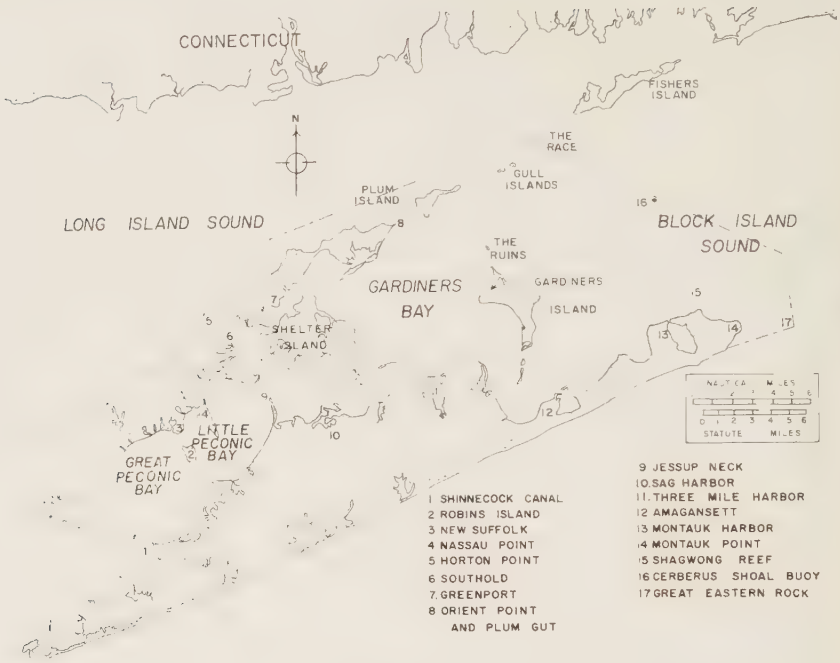

Figure 1. Map of eastern Long Island showing study area (limits indicated by dash line) and important locations in it.

and of the fishing boats of various types in the area. These data were expanded in conjunction with the interview data by the method described by Briggs (1962) to estimate the total number of anglers fishing in the area, the total number fishing for scup, the total catch of all species and the total scup catch.

SPORT FISHERIES IN GENERAL

In the course of obtaining data on the fisheries for scup, information on the sport fisheries in general was recorded.

Facilities Available and Principal Fishing Grounds

Pre-season inventories were made to determine the number of public boat facilities available to anglers within the study area (Table 1). The boat types recognized were defined by Briggs (1962).

Rowboat stations were scattered throughout the area, with a concentration in the Peconic Bays, particularly at Southold and New Suffolk. Others were located at Sag Harbor, Three Mile Harbor, Amagansett, Montauk Harbor and near Orient Point. Anglers who used rental rowboats fished relatively near the stations. Little Peconic Bay, particularly

Table 1. Rowboat, Open Boat and Charter Boat Facilities Available to Anglers in the Study Area *

Facility	1964	1965	1966
Rowboat stations			
All locations	24 (645)	24 (644)	23 (613)
Peconic Bays only	13 (471)	13 (472)	12 (437)
Open boats			
All locations§	24	25	23
Greenport and vicinity	5	5	5
Montauk Harbor	18	18	17
Charter boats			
All locations§	75	79	83
Greenport and vicinity	21	20	20
Montauk Harbor	53	58	61

* Figures in parentheses represent number of boats.
§ Not included are 5 open boats and 24 charter boats berthed in Connecticut that fished at times within the study area (George Maltezos, personal communication).

between Robins Island and Nassau Point, and the areas near Jessup Neck and Southold received the heaviest fishing.

Open boats were berthed at three places: Montauk Harbor, Greenport and the Shinnecock Canal. Montauk Harbor far outstripped the other sites in the number available (Table 1). These boats fished mainly in the vicinities of Montauk Point and Great Eastern Rock when after scup. Five, however, fished offshore near Block Island and on Cox's Ledge for Atlantic cod (*Gadus morhua*) the year round and did not enter the sport fishery for scup. Those based at Greenport fished near Jessup Neck in May and early June. After that, they fished in Gardiners Bay, chiefly the areas near Gardiners Island, The Ruins, Orient Point, Plum Island and the Gull Islands. But they returned to the Peconic Bays when inclement weather forced them away from the preferred grounds and when there were spurts of fair to good angling for weakfish (*Cynoscion regalis*). The open boats berthed at the Shinnecock Canal (there was one in 1964, two in 1965 and one until mid-June of 1966) fished near Jessup Neck in May and early June and in the vicinity of Robins Island later in the year.

The large concentration of charter boats berthed at Montauk Harbor rarely fished for scup. They usually sought pollock (*Pollachius virens*) in the spring and bluefish (*Pomatomus saltatrix*) and striped bass (*Roccus saxatilis*) during the rest of the year, primarily at Shagwong Reef and in the vicinity of Montauk Point. In addition, many fished offshore for bluefin tuna (*Thunnus thynnus*) and white marlin (*Makaira albida*) when they were available. Although those based at Greenport

often came into Little Peconic Bay in May to take advantage of the scup angling there at that time, they preferred to fish for bluefish, striped bass, tautog (*Tautoga onitis*) and summer flounder (*Paralichthys dentatus*) in the vicinities of Orient Point, Plum Island, the Gull Islands, The Race and The Ruins. One Greenport-based boat did fish regularly in Little Peconic Bay throughout each summer, but its prime objective was weakfish. There were charter boats based at the Shinnecock Canal, but they rarely fished in the Peconic Bays. Several moved to Montauk Harbor in the late summer and fall, and these are included in the numbers listed for Montauk Harbor in Table 1.

Private boats were well represented. The Boating Almanac for 1965 (Anonymous, 1965) listed over 65 marinas, boat yards and yacht clubs in the area studied. In addition, many private boats were berthed in creeks adjoining their owners' properties. The Nassau County Fish and Game Association (1964) listed 16 public and 25 commercial launching ramps in the area. However, the ramps at New Suffolk and Montauk Harbor had inadequate parking facilities on several weekends. The two public ramps on Long Island Sound within the study area were in poor condition and difficult to use.

There were few bank and pier fishing sites in relation to the size of the area. However, where there was public access, there usually was some bank and pier angling. The most popular areas were at Sebonac Inlet (about 3½ miles northeast of the Shinnecock Canal), Sag Harbor, Montauk Harbor Inlet, Goose Creek in Southold and Truman Beach in East Marion (on Long Island South about half way between Greenport and Orient Point).

In addition to boats berthed or launched in New York, several open boats, charter boats and private boats from Connecticut were known to fish in the area studied at various times.

Number of Anglers and Composition of Catch

The estimated numbers of anglers that used the various sport-fishing facilities in the area are shown in Table 2. There was essentially the same total in 1964 and 1965, although variations occurred between months and between facilities. In 1966, a slight decline took place which was reflected in the total for each facility except charter boats. In each year, over one-third of the anglers fished from private boats. In 1964, charter boats were the next most popular facility, followed by rowboats and open boats. But in 1965 and 1966, charter boats were used less than rowboats and open boats. The fewest number of anglers fished from banks and piers.

The species composition of the catch of all anglers is shown in Table

TABLE 2. ESTIMATED NUMBER OF ANGLERS WHO USED EACH FACILITY EACH MONTH

Facility	Month							Total
	May	June	July	August	September	October	November	
1964								
Bank and pier	1,542	1,857	2,780	4,723	4,334	1,162	542	16,940
Rowboat	9,272	3,960	8,021	6,973	3,909	1,082	1,168	34,385
Open boat	2,615	3,570	5,135	4,774	1,980	3,067	2,286	23,427
Charter boat	3,418	4,229	7,497	8,618	4,078	3,951	2,822	34,613
Private boat	9,690	6,236	13,383	14,353	7,285	3,155	2,356	56,458
Total	26,537	19,852	36,816	39,441	21,586	12,417	9,174	165,823
1965								
Bank and pier	2,916	1,601	2,341	2,681	3,425	1,669	500	15,133
Rowboat	12,554	3,408	6,479	7,052	4,110	1,871	612	36,086
Open boat	3,260	2,137	6,177	11,399	5,577	2,850	1,050	32,450
Charter boat	1,878	1,444	3,332	6,022	5,879	4,095	1,879	24,529
Private boat	11,295	5,955	9,684	12,799	9,845	5,651	2,141	57,370
Total	31,903	14,545	28,013	39,953	28,836	16,136	6,182	165,568
1966								
Bank and pier	1,747	1,693	2,317	3,301	3,383	870	300	13,611
Rowboat	8,017	4,709	5,799	5,253	3,825	2,038	605	30,246
Open boat	4,145	2,172	5,009	4,914	7,560	4,520	1,190	29,510
Charter boat	1,977	2,571	4,293	5,056	7,023	4,620	1,090	26,630
Private boat	8,846	7,843	10,974	11,393	10,614	4,035	1,706	55,411
Total	24,732	18,988	28,392	29,917	32,405	16,083	4,891	155,408

Table 3. Species Composition of Catch by Anglers in the Study Area

Species	1964		1965		1966	
	Number	Per cent	Number	Per cent	Number	Per cent
Scup	617,315	27.8	1,016,302	44.6	586,687	35.7
Winter flounder	430,808	19.4	374,798	16.5	423,735	25.8
Tautog	306,947	13.8	145,769	6.4	188,075	11.4
Bluefish	272,198	12.3	239,356	10.5	179,801	10.9
"Adult"	(261,736)	(11.8)	(207,369)	(9.1)	(148,175)	(9.0)
"Snapper"	(10,642)	(0.5)	(31,987)	(1.4)	(31,626)	(1.9)
Northern puffer	139,909	6.3	133,248	5.9	125,907	7.7
Black sea bass	197,993	8.9	130,384	5.7	23,888	1.5
Weakfish	27,146	1.2	127,318	5.6	29,799	1.8
Northern kingfish	90,673	4.1	46,824	2.1	26,543	1.6
Striped bass	73,712	3.3	21,074	0.9	28,845	1.8
Summer flounder	13,885	0.6	31,345	1.4	14,031	0.9
Other*	47,147	2.1	11,900	0.5	18,074	1.1
Total	2,217,733	99.8	2,278,318	100.1	1,645,385	100.2

* Includes those species which did not comprise at least 1 per cent of the tota catch in any one year: Atlantic cod, Atlantic mackerel, American eel, cunner' Atlantic tomcod, pollock, windowpane, blue shark, smooth dogfish, sea herring' butterfish, Atlantic bonito, white hake and silver hake. Other species often caught by the anglers, but not kept, included two species of sea robin, two species of sculpin, oyster toadfish, various species of skate, spiny dogfish, and large individuals of Atlantic silverside, mummichog and striped killifish.

3. There were 24 species of fish kept by the anglers. Several other species were caught and discarded. The total catch was about the same in 1964 and 1965, but it was considerably lower in 1966. During the study, the scup was the most important species taken. It was harvested by anglers using all the facilities, but it was of greatest importance to those using rowboats and open boats. The winter flounder (*Pseudopleuronectes americanus*) was next in importance.[2] Tautog usually ranked third. Bluefish were important as adults to the charter boat and private boat fishermen and as immature fish ("snappers") to the bank and pier anglers. Striped bass and weakfish were of prime importance to elements of the charter boat and private boat fleets. The other species were usually of secondary importance.

FISHERIES FOR SCUP

Data on the fisheries for scup pertained to both the number of anglers participating and the nature of the catch.

Number of Anglers

The estimated total number of scup anglers was about the same in

[2] The sport fisheries for this fish were discussed by Briggs (1965).

1965 as it was in 1964 with declines in the numbers fishing from banks and piers, charter boats and private boats compensated for by an increase in the number fishing from open boats (Table 4). In 1966, fewer anglers sought scup (52,473), the number declining for all the facilities except private boats. Each year, scup anglers comprised slightly over one-third of all the anglers that fished in the area (Table 5). Together, each year, rowboats and open boats attracted two-thirds, or more, of all the scup anglers (Table 4). Between 60 and 67 per cent of all the anglers using rowboats and open boats were scup anglers (Table 5), but, at the height of the summer vacation season, the proportion reached as high as 87 per cent for rowboats and 100 per cent for open boats. Between 18 and 23 per cent of all scup anglers used private boats (Table 4), while scup anglers comprised between 18 and 24 per cent of all private boat anglers (Table 5). Only 4 to 6 per cent of all scup anglers fished from charter boats (Table 4), and they comprised from 9 to 10 per cent of all charter boat anglers (Table 5). A higher proportion of charter boat anglers sought scup from May through July than in later months. By August, bluefish trolling and jigging had become the major support of the charter boat fleet. July and August of 1964 were the only months in which there was a significant number of scup anglers among the bank and pier fishermen.

Scup were sought by anglers using the various facilities from May through October. The month of September usually signified the end of the scup fishing season although a few anglers did seek them in October. The large number of open boat anglers seeking scup in October of 1966 was exceptional and was brought about by scup staying in the vicinities of Montauk Point and Great Eastern Rock later than usual. Perhaps this was due to above-average water temperatures during the early part of the month. The summer vacation months of July and August usually brought out the most scup anglers. However, rowboats were generally used by scup anglers to the greatest degree in May. Each year, in May, June and July, the rowboat fishing attracted more scup anglers than any other type. In August, September and October, open boats were usually used by more scup anglers than any other facility. From July through October, most of the open boat anglers that fished for scup used boats based at Montauk Harbor. This major portion of the open boat fleet did not fish for scup in May and early June. The first recorded trips for scup by open boats based at Montauk Harbor were on June 10 in 1964, June 15 in 1965 and June 27 in 1966. In May and early June, almost all scup anglers fished in the Peconic Bays. Throughout each year, most of the scup anglers who used rowboats were also concentrated in the Peconic Bays.

Many of the anglers that fished for scup also fished for other species

Table 4. Estimated Number of Anglers Who Sought Scup According to Facility and Month

Facility	Month							Total	
	May	June	July	August	September	October	November	Number	Per cent
1964									
Bank and pier	0	0	905	1,586	303	0	0	2,794	4.9
Rowboat	4,468	2,954	6,939	5,629	2,314	57	0	22,361	39.2
Open boat	716	2,938	4,899	4,774	1,699	269	0	15,295	26.8
Charter boat	0	641	1,885	511	415	0	0	3,452	6.1
Private boat	600	2,650	4,174	4,063	1,609	0	0	13,096	23.0
Total	5,784	9,183	18,802	16,563	6,340	326	0	56,998	100.0
1965									
Bank and pier	108	75	327	333	0	0	0	843	1.5
Rowboat	8,817	2,291	4,456	3,988	2,242	276	0	22,070	38.3
Open boat	1,981	1,145	4,431	10,005	4,109	144	0	21,815	37.8
Charter boat	578	351	1,018	455	125	0	0	2,527	4.4
Private boat	3,827	1,299	2,495	1,995	657	114	0	10,387	18.0
Total	15,311	5,161	12,727	16,776	7,133	534	0	57,642	100.0
1966									
Bank and pier	0	0	32	268	47	0	0	347	0.7
Rowboat	4,416	3,920	4,163	3,230	2,295	150	0	18,174	34.6
Open boat	1,096	1,182	2,723	4,515	7,384	2,576	0	19,476	37.1
Charter boat	367	505	983	108	364	0	0	2,327	4.4
Private boat	2,225	3,137	2,807	2,320	1,281	379	0	12,149	23.2
Total	8,104	8,744	10,708	10,441	11,371	3,105	0	52,473	100.0

TABLE 5. PERCENTAGE OF ALL ANGLERS IN EACH FACILITY EACH MONTH WHO SOUGHT SCUP

Facility	Month							Season
	May	June	July	August	September	October	November	
1964								
Bank and pier	0.0	0.0	32.6	33.6	7.0	0.0	0.0	16.5
Rowboat	48.2	74.6	86.5	80.7	59.2	5.3	0.0	65.0
Open boat	27.4	82.3	95.4	100.0	85.8	8.8	0.0	65.3
Charter boat	0.0	15.2	25.2	5.9	10.2	0.0	0.0	10.0
Private boat	6.2	42.5	31.2	28.3	22.1	0.0	0.0	23.2
Total	21.8	46.3	51.1	42.0	29.4	2.6	0.0	34.4
1965								
Bank and pier	3.7	4.7	14.0	12.4	0.0	0.0	0.0	5.6
Rowboat	70.2	67.2	68.8	56.6	54.6	14.8	0.0	61.2
Open boat	60.8	53.6	71.7	87.8	73.7	5.1	0.0	67.2
Charter boat	30.8	24.3	30.5	7.6	2.1	0.0	0.0	10.3
Private boat	33.9	21.8	25.8	15.6	6.7	2.0	0.0	18.1
Total	48.0	35.5	45.4	42.0	24.7	3.3	0.0	34.8
1966								
Bank and pier	0.0	0.0	1.4	8.1	1.4	0.0	0.0	2.5
Rowboat	55.1	83.2	71.8	61.5	60.0	7.4	0.0	60.1
Open boat	26.4	54.4	54.4	91.9	97.7	57.0	0.0	60.0
Charter boat	18.6	19.6	22.9	2.1	5.2	0.0	0.0	8.7
Private boat	25.2	40.0	25.6	20.4	12.1	9.4	0.0	21.9
Total	32.8	46.1	37.7	34.9	35.1	19.3	0.0	33.8

such as tautog, black sea bass (*Centropristes striatus*), weakfish and summer flounder on the same trip. However, except for one of the open boats and most of the charter boats based at Greenport and the rowboats based at Orient Point, scup was nearly always the most desired species on combination trips. On the other hand, Neville *et al.* (1939) noted that in 1938 scup were considered secondary to weakfish in the Peconic Bays and to black sea bass at Montauk, but comparisons with their observations were difficult to make. Their data were computed separately for Montauk and the Peconic Bays, and they treated only open boats and charter boats at Montauk and only open boats, charter boats and rowboats in the Peconics. They also used different techniques in

collecting and analyzing their data than were employed in the present study.

The same authors recorded 7,731 rowboat anglers seeking scup in the Peconic Bays in 1938. In the present study the corresponding figure for the entire area surveyed ranged from 18,174 to 22,316. Since most of the scup angling from rowboats from 1964 through 1966 was concentrated in the Peconics, it seems evident that such angling there has increased greatly since 1938.

They also recorded 1,259 scup anglers fishing from open boats in the Peconics and 13,392 at Montauk in 1938. Compared with the range of 15,295 to 21,815 for the present study, these figures indicate less of an increase than that for scup angling from rowboats. In all probability, the most important change in scup angling from open boats since 1938 has been that this species has become a preferred rather than a secondary fish on combination trips.

With respect to charter boats, on the other hand, they recorded 522 scup anglers at Montauk and 7,583 in the Peconic Bays in 1938. During the present study the range was 2,327 to 3,425, indicating that anglers using these facilities fished more heavily for scup in 1938. However, it must be taken into account that many, if not most, of these anglers in 1938 sought this fish as a supplement to weakfish angling which has now declined. For example, in 1965, charter boats landed 11,113 weakfish and attracted 977 weakfish anglers. In 1938, during the 2-week period from May 16 to 31 alone, 215,434 weakfish were taken by 10,059 anglers fishing from charter boats in the Peconic Bays (Nesbit, 1939).

Nature of Catch

Scup were caught from May through November (Table 6), although, usually, few were taken after September. The open boat catch of 44,524 in October 1966 (mostly from the vicinities of Montauk Point and Great Eastern Rock) was considered exceptional. The estimated total catch fluctuated from 617,315 in 1964 to 1,016,302 in 1965 and 586,687 in 1966. Most of the fluctuations could be accounted for by variations in the number taken by open boat anglers. Together, rowboat anglers and open boat anglers accounted for over two-thirds of all the scup taken each year. Charter boat anglers took more than 40,000 scup in 1964 and 1965, but only 20,765 in 1966. Bank and pier anglers took relatively few, only 696 in 1966. The proportions of scup in the catch of all fish by anglers using the various facilities each year are given in Table 7. Scup were most important to the rowboat and open boat anglers.

Open boat anglers usually had their greatest scup catches in July, August and September, most of which were taken in the vicinities of Montauk Point and Great Eastern Rock. In many months, scup ap-

TABLE 6. ESTIMATED SCUP CATCH FOR EACH FACILITY EACH MONTH

Facility	Month							Total	
	May	June	July	August	September	October	November	Number	Per cent
1964									
Bank and pier	0	0	4,542	4,743	457	0	0	9,742	1.6
Rowboat	78,090	11,584	72,724	44,172	16,367	77	16	223,030	36.1
Open boat	21,649	21,391	55,442	76,431	23,073	405	0	198,391	32.1
Charter boat	0	8,763	21,568	4,002	7,013	0	0	41,346	6.7
Private boat	10,515	25,008	51,431	48,854	8,976	22	0	144,806	23.5
Total	110,254	66,746	205,707	178,202	55,886	504	16	617,315	100.0
1965									
Bank and pier	54	125	618	715	474	0	0	1,986	0.2
Rowboat	135,946	6,276	37,792	36,965	12,948	971	0	230,898	22.7
Open boat	18,472	22,585	98,057	316,513	167,313	455	0	623,395	61.4
Charter boat	12,072	3,612	17,235	8,892	999	0	0	42,810	4.2
Private boat	61,257	3,846	29,625	17,654	4,337	494	0	117,213	11.5
Total	227,801	36,444	183,327	380,739	186,071	1,920	0	1,016,302	100.0
1966									
Bank and pier	0	0	32	618	46	0	0	696	0.1
Rowboat	120,077	57,088	16,381	12,216	9,347	208	0	215,317	36.7
Open boat	19,033	12,551	13,881	44,152	90,834	44,524	23	224,998	38.4
Charter boat	8,606	3,194	4,058	1,722	3,185	0	0	20,765	3.5
Private boat	48,076	23,952	11,580	24,860	14,624	1,819	0	124,911	21.3
Total	195,792	96,785	45,932	83,568	118,036	46,551	23	586,687	100.0

Table 7. Percentage of Scup in the Catch of All Species for Each Facility Each Month

Facility	Month							Season
	May	June	July	August	September	October	November	
1964								
Bank and pier	0.0	0.0	22.4	23.9	2.0	0.0	0.0	11.3
Rowboat	32.8	21.5	54.3	44.3	29.1	0.6	0.1	36.6
Open boat	38.0	28.0	55.1	70.8	48.4	0.6	0.0	37.7
Charter boat	0.0	14.3	23.6	6.8	17.7	0.0	0.0	11.0
Private boat	6.7	33.4	39.6	31.8	16.7	0.1	0.0	23.3
Total	21.4	24.1	43.2	40.5	25.4	0.3	0.1	27.8
1965								
Bank and pier	0.4	1.2	7.8	6.4	1.4	0.0	0.0	2.3
Rowboat	61.9	14.0	48.6	53.0	29.2	3.9	0.0	47.3
Open boat	41.1	51.3	68.7	75.7	80.2	1.3	0.0	68.3
Charter boat	34.9	17.6	41.7	17.6	1.7	0.0	0.0	16.9
Private boat	33.2	6.2	41.3	18.6	9.0	1.0	0.0	21.9
Total	45.7	20.0	53.7	59.1	46.9	1.3	0.0	44.6
1966								
Bank and pier	0.0	0.0	0.4	4.5	0.2	0.0	0.0	1.0
Rowboat	59.2	42.8	34.5	38.8	29.1	1.1	0.0	45.6
Open boat	21.5	44.5	45.4	75.5	61.6	56.3	0.1	49.1
Charter boat	17.8	12.9	20.6	7.6	5.5	0.0	0.0	10.1
Private boat	25.2	39.7	28.6	42.0	25.1	7.6	0.0	28.0
Total	36.5	37.5	31.3	43.5	36.6	30.4	0.1	35.7

proached or exceeded 50 per cent of all fish caught by these anglers. This figure reached 80.2 per cent in September of 1965. In the preceding month the catch of 316,513 had exceeded that of any other facility for the entire year.

Rowboat anglers had their peak scup catches in May, amounting to over half the scup taken by these anglers in 1965 and 1966, following which there was a sharp drop in June. In 1964 and 1965, the catch increased in July, but in 1966 it continued to drop. Despite the usually low catches after May, scup often comprised over 40 per cent of all the fish taken in July and August. Most of the scup caught by rowboat anglers were taken in the Peconic Bays.

Scup catches by anglers using private boats and charter boats showed

a pattern generally similar to that of those by rowboat anglers, i.e., high in May followed by a drop in June with a recovery later in the year. These two facilities were, however, less dependent than the others upon scup, and only rarely during July and August did scup comprise more than 40 per cent of their total catch. Again, comparisons with the data of Neville *et al.* (1939) were difficult to make. However, it appears that the scup catch has generally increased since 1938 for all facilities except charter boats in the Peconic Bays. In 1938, the catch at Montauk was 149,124 for open boats and 7,796 for charter boats, while in the Peconics it was only 27,996 for rowboats, 12,759 for open boats and 52,466 for charter boats.

Catch Per Effort

Since catch-per-effort (fish per angler per trip) data were derived solely from the angler interviews and were not subject to expansion by the airplane observations, they could be calculated separately for open boats based at Montauk Harbor, open boats that fished Gardiners Bay and the Peconic Bays and rowboats that fished the Peconic Bays, as well as for the study area as a whole. This enabled more detailed comparison between the facilities in the study area and more direct comparison with the data of Neville *et al.* (1939) as shown in Table 8.

Except for the open boats based at Montauk Harbor, catch per effort was usually highest in May when scup angling was concentrated in the Peconic Bays, particularly in Little Peconic Bay near Jessup Neck. Scup were first taken in the Peconics each year on May 6 by rowboat anglers seeking winter flounder. By May 12 in 1964, May 10 in 1965 and May 17 in 1966, the best rowboat anglers were catching more than 100 scup per boat, and the highest catches per effort for these anglers occurred in May. The rate of catch dropped in June. In 1964 and 1965, the lowest rates for rowboat anglers between May and September occurred in June and were followed by somewhat of a recovery from July through September. In 1966, the drop in June was not as great, but there was no recovery in the following months and the lowest midsummer catches per effort were recorded. Since most rowboat angling for scup was in the Peconic Bays, the catch per effort there was in close agreement with that for all rowboat anglers. Comparison with data for 1938 indicated that, except for July through September in 1966, the catch per effort was generally much higher during the present study.

Open boat anglers who fished in Gardiners Bay and the Peconic Bays usually had their highest catches per effort in May, while those who fished in the vicinities of Montauk Point and Great Eastern Rock usually had their highest catches per effort in August and September. Since most of the open boats in the study area were berthed at Montauk Har-

Table 8. Comparative Catch Per Effort for Scup in 1938 and in 1964, 1965 and 1966 According to Facility and Month

Facility	Month						
	May	June	July	August	September	October	November
1938*							
Rowboat (Peconic Bays)	1.1	1.4	5.8	6.1	4.6	§	§
Open boat (Montauk)	§	7.8	13.0	13.6	6.0	0.6	0.2
1964							
Bank and pier	§	§	4.4	2.8	1.2	§	§
Rowboat							
Entire area	18.4	3.9	10.4	7.7	6.9	0.3	§
Peconic Bays	18.4	4.0	12.4	8.6	8.7	0.3	§
Open boat							
Entire area	30.2	7.3	11.3	16.0	13.6	1.5	§
Peconic Bays and Gardiners Bay	30.2	9.5	11.2	9.2	9.3	1.4	§
Montauk	§	3.6	11.5	24.7	20.7	1.7	§
Charter boat	§	13.7	11.5	7.8	16.7	§	§
Private boat	17.5	9.5	12.3	12.0	5.5	§	§
1965							
Bank and pier	0.5	0.7	1.3	2.0	§	§	§
Row boat							
Entire area	15.3	2.6	8.1	8.4	5.6	3.2	§
Peconic Bays	15.5	2.5	7.6	8.9	6.0	3.8	§
Open boat							
Entire area	9.3	19.1	21.9	31.6	40.5	1.0	§
Peconic Bays and Gardiners Bay	9.3	6.8	7.7	9.3	9.7	1.0	§
Montauk	§	32.7	29.2	46.0	46.6	§	§
Charter boat	20.9	9.5	16.9	19.3	8.0	§	§
Private boat	16.0	2.8	12.0	8.4	6.3	4.3	§
1966							
Bank and pier	§	§	0.0	2.3	1.0	§	§
Row boat							
Entire area	30.0	14.6	3.9	3.6	3.8	1.2	§
Peconic Bays	30.0	14.7	3.2	2.9	3.6	1.0	§
Open boat							
Entire area	17.3	10.5	5.0	9.8	12.3	17.3	§
Peconic Bays and Gardiners Bay	17.3	11.1	4.5	5.9	4.0	0.9	§
Montauk	§	7.2	5.2	10.9	15.6	18.4	§
Charter boat	23.4	6.3	3.7	15.8	4.9	§	§
Private boat	19.9	7.6	3.9	10.6	10.0	4.8	§

* Adapted from Neville *et al.* (1939).

§ Scup were not actively sought by anglers who used this facility at this time. Any scup caught by them were incidental while other species were sought.

bor, that group exerted a strong influence on the rate of catch for this facility throughout the entire area. Except in May (when they did not seek scup) and June, the catch per effort for this group was higher than that for other open boats and was generally the highest achieved by any of the facilities. Even in the summer of 1966, when scup catches were generally much lower than in other years, the open boats based at Montauk Harbor led all the other facilities in catch per effort in July, September and October. In 1964 and 1965 the Montauk boats regularly had higher rates of catch than in 1938, but in 1966 this did not occur until September. The rise of scup from a secondary role to that of the preferred species on combination trips undoubtedly has been a factor in the generally increased catches per effort since 1938. An increase in the size of the scup population since then also could have brought this about, but there are no data to either prove or disprove this possibility.

In 1964 and 1965, the catch per effort of charter boat and private boat anglers followed a generally similar pattern to that of rowboat anglers, i.e., high in May, followed by a decline in June, with somewhat of a recovery later in the year. However, in 1966, it did not follow the continued decline recorded for rowboat angling.

Bank and pier anglers, when they sought scup, had a lower rate of catch than did anglers using the boat facilities.

Size of Scup Taken in the Peconic Bays

The average size of scup caught by rowboat anglers in the Peconic Bays is shown in Table 9. Analysis of variance (Table 10) indicated significant differences between years and months. Average fork length was highest in May and declined significantly each month until the season ended (May vs. June, $t = 17.89$; June vs. July, $t = 12.27$; July

Table 9. Average Fork Length (in Millimeters) for Scup Taken by Rowboat Anglers in the Peconic Bays Each Month *

Year	Month					Total
	May	June	July	August	September	
1964	281 (272)	254 (132)	229 (276)	214 (459)	189 (190)	231 (1,329)
1965	270 (437)	228 (206)	221 (426)	212 (471)	206 (124)	231 (1,664)
1966	285 (337)	255 (654)	239 (323)	221 (368)	205 (141)	247 (1,823)
Average	278 (1,046)	249 (992)	229 (1,025)	215 (1,298)	198 (455)	237 (4,816)

* Figures in parentheses represent number of fish in each case.

Table 10. Analysis of Variance for Data Given in Table 9.

Source of variation	Degrees of freedom	Sum of squares	Mean square	*F*	
				Value	Reference value*
Total	4,815	9,875,506			
Months	4	1,838,982	459,745.5	344.69	3.32
Years	2	282,276	141,138.0	105.48	4.60
Months vs. years interaction	8	1,350,489	168,811.1	126.56	2.51
Within subclasses	4,801	6,403,809	1,333.8		

* At 1 per cent level of probability.

vs. August, $t = 9.18$; August vs. September, $t = 8.54$). The average for the entire season in 1966 was significantly greater than that in 1964 ($t = 12.15$) and 1965 ($t = 12.91$).

In May, large fish (255 millimeters or more in fork length) dominated the catch (Table 11). As the season progressed, the proportion of large fish in the catch declined and that of small fish (0 to 200 milli-

Table 11. Percentage of Small, Medium and Large Scup Taken by Rowboat Anglers in the Peconic Bays

Size*	Month					Season
	May	June	July	August	September	
1964						
Small	4.8	12.9	20.7	42.7	58.9	29.8
Medium	20.6	40.2	56.9	42.9	36.3	41.5
Large	74.6	47.0	22.5	14.4	4.7	28.7
1965						
Small	0.2	36.4	39.2	46.7	42.7	31.0
Medium	37.8	39.3	39.9	42.5	42.5	41.2
Large	62.0	24.3	20.9	10.8	3.2	27.8
1966						
Small	0.9	3.1	11.1	22.8	54.6	12.1
Medium	21.1	55.2	60.1	63.6	36.2	50.0
Large	78.0	41.7	28.8	13.6	9.2	38.0

* Size categories, in fork length, were: small, 0 to 200 millimeters; medium, 205 to 250 millimeters; large, 255 or more millimeters.

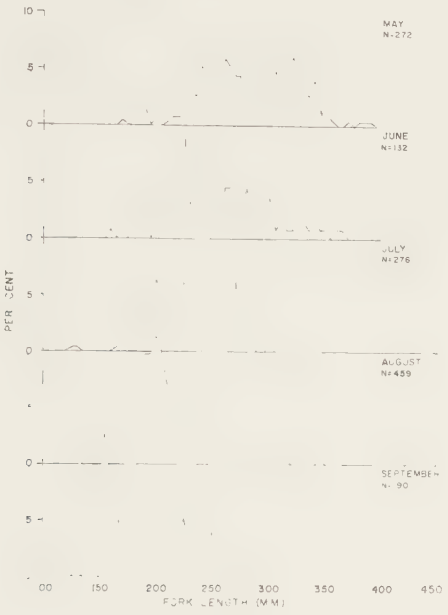

Figure 2. Monthly length-frequency distribution for scup caught by rowboat anglers in the Peconic Bays in 1964.

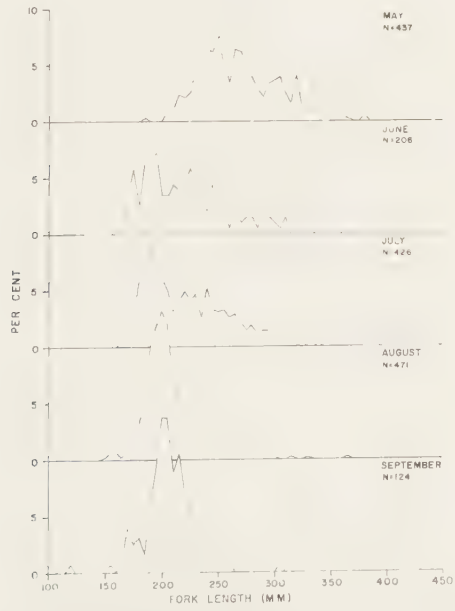

Figure 3. Monthly length-frequency distribution for scup caught by rowboat anglers in the Peconic Bays in 1965.

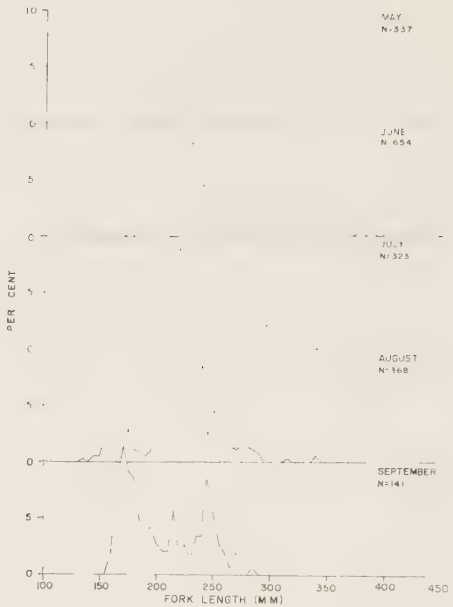

Figure 4. Monthly length-frequency distribution for scup caught by rowboat anglers in the Peconic Bays in 1966.

meters in fork length) increased. By September, small fish usually were dominant. In 1966, a lesser proportion of small fish than in other years were caught from June through August. This appears to have been the most likely reason for the higher average length for the season in 1966 than in 1964 and 1965.

The reason for the decline in the proportion of large fish in the catch in the Peconic Bays as the season progressed could have been either an influx of small fish into the area, a movement of large fish out of the area or some combination of such movements. Since the catch per effort was lower after May, suggesting a reduced population, the latter two possibilities seem to offer the best explanation.

The size distribution of scup caught by rowboat anglers in the Peconic Bays is shown in Figures 2 to 4. Although there is general agreement in the pattern of the larger fish having been taken early in the season and the smaller ones later, there was a large group under 185 millimeters in fork length present in the September 1964 and 1966 catches that was not represented in 1965. Likewise, there was a large group about 200 millimeters in fork length present in the catches from July through September in 1964 and 1695 that was not represented in 1966. This appears to indicate a missing year class and would help to explain the poorer-than-usual catches and rates of catch in the summer

of 1966. This also could explain the lower-than-usual proportion of small scup in the catch from June through August in 1966.

Size of Scup Taken at Montauk

The logistics of the study made it impossible to acquire pertinent data on the size of scup caught by anglers using open boats based at Montauk Harbor. When observed by the author while collecting other data, these scup did appear to be larger than those taken at the same time of year in the Peconic Bays. However, in the absence of length measurements for specimens from the Montauk area, no conclusions regarding relative size composition can be drawn. Neville *et al.* (1939) did state that, in 1938, the size of commercially landed scup was greater in the "Gardiners-Montauk region" (180 to 305 millimeters) and in the "Montauk offshore area" (180 to 280 millimeters) than in the "Peconic bays region" (150 to 200 millimeters). Examination of their Figure 28 (1939) indicates that this was also true for the Montauk sport fishery in September and possibly August.

Length-weight Relationship

The length-weight relationship for 4,824 scup caught by rowboat anglers between May and October from 1964 through 1966 was calculated using the method of least squares. The resultant equation was:

$$\log W = -4.3944 + 2.8941 \log L$$

in which W represents weight in grams and L represents fork length in millimeters. The regression curve is shown in Figure 5. The calculated weights in grams at 25-millimeter intervals in fork length and at the minimum and maximum sizes measured are given in Table 12.

DISCUSSION

Scup have long been an important sport fish in New York waters. As early as 1842, DeKay wrote "It affords much sport to fishing parties, who go outside the harbor in steam vessels and take them in great numbers." In the area covered by this study, scup were of great importance to rowboat anglers in the Peconic Bays and to open boat anglers in the waters off Montauk Point. The former had their highest catches and catches per effort in May, while the latter were most successful from July through September (and occasionally October).

Scup have been known to suffer periods of decline and then return to their former abundance. Bean (1901) wrote "The fishery fluctuates greatly: in some years the scup is relatively scarce and in others extremely abundant." Neville *et al.* (1939), while acknowledging periods of decline and abundance throughout its geographical range stated

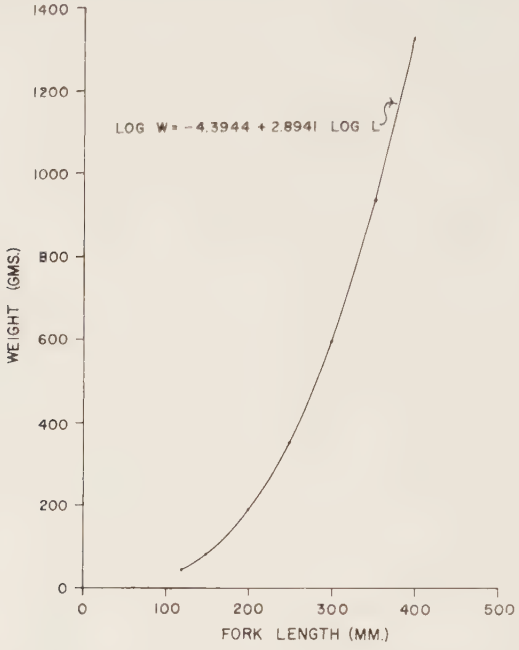

Figure 5. Regression curve for the length-weight relationship of 4,824 scup (range 120 to 395 millimeters in fork length) caught by rowboat anglers in the Peconic Bays from 1964 to 1966.

Table 12. Calculated Weight of Scup at Various Lengths

Fork length (millimeters)	Calculated weight (grams)
120*	42
125	47
150	80
175	125
200	184
225	259
250	351
275	463
300	595
325	750
350	930
375	1,130
395*	1,319

* Smallest and largest scup weighed and measured.

". . . such fluctuations in the past have not been strikingly evident in New York". They went on to predict "A natural decline in abundance . . . may be expected sooner or later." It appears that a decline did occur in

1966 for the sport fishery in the waters of eastern Long Island and for Long Island's commercial fishery. New York Landings for October 1966 (Anonymous, 1967) showed a commercial catch of 3,827,553 pounds of scup for the first 10 months of 1966, compared with 7,069,410 pounds for the corresponding period in 1965. It has been shown that an apparent year-class failure prior to 1965 was the probable cause for a decline in the sport fishery for scup in the summer of 1966. Neville and Talbot (1964) showed that the fluctuations in the summer commercial fisheries for scup in the 1920's and early 1930's were caused by ". . . the size of the increments added to the population by succeeding year classes, which apparently have been caused by variations in relative success of reproduction of annual broods". Therefore, it would seem that the probable cause for the decline in New York's commercial catch in 1966 was the same missing year class that apparently affected the sport fishery. Since Neville and Talbot also showed that a large reserve of old fish is not necessary for successful reproduction, there appears to be no need for restrictions upon the sport fishery for scup. However, to improve their catches, anglers might well consider making greater use of facilities available in the Peconic Bays in May and of open boats based at Montauk Harbor from July through September.

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GENERAL NOTES

ZOOPLANKTON OF THE ADIRONDACKS

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There have been few limnological studies of the lakes in the Adirondack region of New York. Fishery biologists are well aware of the low productivity of these waters, which lie within a region of ancient granitic rock. Berg (1963) reviewed the general water chemistry of 14 Adirondack lakes, all of which are acid (pH 4.9 - 6.4) and low in carbonates (total alkanity <20 milligrams per liter). In previous studies of the zooplankton of the region[1], identifications were limited to the generic level.

This paper describes the occurrence of crustacean zooplankton species in 36 lakes and ponds representative of the major drainage basins in the Adirondack region. Together with similar data for the Finger Lakes region (Hall and Waterman, 1967), this information may be useful to fisheries biologists studying the relationship between zooplankton and the survival of young fish.

Figure 1. Map of northern New York showing the principal drainages of the Adirondack region and the locations of the waters studied.

[1] In reports of biological surveys of the several watersheds of the region published as supplements to the annual reports of the Conservation Department for the years 1929 to 1934.

Plankton was collected from nine large lakes (Figure 1) in June and October of 1965, using a 12-inch-diameter, #20-mesh plankton net tied to a weighted line so as to sample during vertical lowering and the long diagonal return. Two small lakes at altitudes over 2,760 feet were similarly sampled during the same months

Table 1. Species of Zooplankton Recorded for Selected Adirondack Lakes

Species	High-altitude lakes		Large lakes								
	Lake Colden	Avalanche Lake	Raquette Lake	Blue Mountain Lake	Long Lake	Tupper Lake	Upper Saranac Lake	Lower Saranac Lake	Lake Placid	Schroon Lake	Indian Lake
Epischura lacustris	.	.	x	x	§	x	x	x	x	x	x
Diaptomus											
minutus	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*	x*
oregonensis	.	.	.	.	.	.	.	x*	.	.	x*
sanguineus	.	.	.	.	.	x	.	.	.	x	x
leptopus	.	.	.	.	.	.	.	.	.	.	.
Cyclops											
vernalis	x	x	x	.	.	.	x	x	.	.	
bicuspidatus thomasi	.	.	.	.	.	.	.	.	.	x	.
scutifer	.	.	x	.	.	x	x	x	x	.	x
Mesocyclops edax	.	.	x	x	x	x	x	x	x	x	x
Macrocyclops albidus	x	x	.	.	.	.	.	.	.	.	.
Tropocyclops prasinus	.	.	x	x	x	.	.	§	.	.	x
Eucyclops speratus	.	x	.	.	.	.	.	.	.	.	.
Cyclopoid sp.	x	.	.	x	.	.	.	.	x	.	.
Leptodora kindtii	.	.	x	x	x	.	x	.	x	x	x
Polyphemus pediculus	x	x	x	x	x	x	.	.	.	x	x
Sida crystallina	.	.	.	.	.	.	.	.	x	x	.
Diaphanosoma leuchtenbergianum	.	.	x	x	x	x	.	.	.	x	.
Holopedium gibberum	x	.	x*	x*	x	x*	x	x*	x*	x*	x*
Daphnia											
pulex	§	.	x	.	.	.	x	x	x*	.	.
catawba	.	.	x	.	x	x*	x	x	x	x	x*
retrocurva	.	.	.	.	.	.	.	.	.	.	.
longiremis	.	.	.	.	.	x	x	.	x	x	.
ambigua	.	.	.	.	.	.	.	x	.	.	.
dubia	.	.	x	x*	x	x*	x*	x*	x	x*	x
galeata mendotae	.	.	.	x	.	x	x	x*	x	x	.
sp.	.	x	.	.	.	.	.	.	.	.	.
Bosmina longirostris	.	.	x*	x*	x	x*	x	x	x*	x*	x*
Acroperus harpae	x	.	.	.	.	.	.	.	.	.	.
Chydorus sphaericus	§	.	x	.	x	.	x	x	.	.	.
Ceriodaphnia sp.	.	.	.	.	.	.	.	.	.	.	.
Total number of species	9	6	14	13	12	13	14	15	14	15	13

* Exceptionally abundant species in terms of the total zooplankton population in the same lake.

§ Identification questionable because of immature or incomplete specimens.

Table 2. Species of Zooplankton Recorded for Certain Lakes and Ponds on the Adirondack League Club and Brandon Park

Species	Brandon Park						Adirondack League Club																	
	Bear Pond	Black Pond	Wolf Pond	Long Pond	Follensby Junior Pond	Honnedaga Lake	Jones Lake	Deer Lake	Otter Lake	Goose Lake	Upper Sylvan Pond	Lower Sylvan Pond	Rock Pond	Chambers Lake	Little Moose Lake	Panther Lake	East Pond	Mountain Pond	Canachagala Lake	Combs Lake	Green Lake	First Bisby Lake	Second Bisby Lake	Third Bisby Lake	Fourth Bisby Lake
Epischura lacustris	:	:	:	:	:	:	:	:	:	:	:	×	×	×	×	×	×	×	×	×	:	×	×	:	:
Diaptomus																									
minutus	:	×	:	:	:	×	×	:	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
oregonensis	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
sanguineus	:	:	:	:	:	:	:	:	×	×	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
leptopus	:	:	:	:	:	:	:	×	:	:	:	:	∞	∞	:	:	×	:	:	:	:	×	×	×	×
Cyclops																									
vernalis	:	:	:	:	∞	:	:	:	:	:	:	:	∞	:	:	:	:	:	:	:	:	:	:	:	:
bicuspidatus thomasi	:	∞	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
scutifer	:	:	:	:	:	×	:	:	:	:	:	:	:	:	:	:	×	:	:	:	:	:	:	:	:
Mesocyclops edax	×	:	×	×	×	×	∞	×	×	:	×	×	×	×	×	:	×	×	×	:	:	×	×	∞	×
Macrocyclops albidus	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
Tropocyclops prasinus	:	:	:	:	:	:	:	×	:	:	:	:	:	:	:	:	:	:	:	:	∞	:	:	×	:
Eucyclops speratus	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:

Cyclopoid sp.						x																x			
Leptodora kindtii													x						x				x	x	
Polyphemus pediculus																								x	
Sida crystallina														x*							x	x*	x*	x	
Diaphanosoma leuchtenbergianum					x		x		x	x	x	x*	x*		x			x	x*						
Holopedium gibberum	x	x*	x*		x		x*			x*	x	x	x*	x		x	x			x*	x*	x	x	x*	x*
Daphnia																									
pulex						x	x	x	x	x				x*							x			x	
catawba	x*		§			x	x*	x*	x*		x*	x*	x*		x*	x*	x	x	x	x	x*	x*		x*	x*
retrocurva					x*																				
longiremis																									
ambigua																									
dubia				§																				x	
galeata mendotae	x*																								
sp.																									
Bosmina longirostris	x*	x*	x*		x*	x			x		x*	x	x	x	x			x	x	x*		x	x		x
Acroperus harpae																									
Chydorus sphaericus					§																				
Ceriodaphnia sp.					x*																				
Total number of species	6	3	5	2	8	7	6	5	7	5	7	7	10	7	6	5	6	4	7	6	5	8	7	10	9

* Exceptionally abundant species in terms of the total zooplankton population in the same lake.
§ Identification questionable because of immature of incomplete specimens.

with a 6-inch, #20-mesh plankton net. In the laboratory the authors independently examined the samples and slide-mounted specimens of all species encountered. In addition, material from 25 lakes on the Adirondack League Club property and Brandon Park, sampled by C. C. Schofield between August and October in 1960, was examined in much the same manner. Obviously some rare species were not collected due to spatial or temporal distribution, but the authors believe that the great majority of all crustacean species of zooplankton in these lakes were recorded. Identifications were made using the keys of Edmondson (1959) and Brooks (1957).

Sample size and frequency were held to minimum levels consistent with the purpose of the investigation. Designation of species found to be exceptionally abundant in terms of the total zooplankton population in the same lake was the only quantification that seemed justified.

The results are summarized in Tables 1 and 2. A total of 30 species is reported, of which 17 are cladocerans and 13 are copepods. In addition, the planktonic larva of the insect *Chaoborus* was found in 16 lakes. Six species, which are both widespread and abundant, were recorded in 20 or more lakes: *Epischura lacustris, Diaptomus minutus, Mesocyclops edax, Holopedium gibberum, Daphnia catawba* and *Bosmina longirostris.* Three others, *Daphnia longiremis, D. galeata mendotae* and *Diaptomus sanguineus,* were found only in the larger lakes, and *Daphnia dubia,* which occurred in all the larger lakes, was found in only one small lake. *Diaptomus leptopus* was found only in Adirondack League Club lakes, and each of the following eight species was found in only one or two lakes: *Diaptomus oregonensis, Cyclops bicuspidatus thomasi, Macrocyclops albidus, Eucyclops speratus, Acroperus harpae, Daphnia ambigua, D. retrocurva* and *Ceriodaphnia* sp. As a group, the larger lakes were found to have decidedly more species than the smaller lakes and ponds.

The list of species recorded for these Adirondack waters is remarkably similar to that for the Finger Lakes (Hall and Waterman, 1967) which are deep glacial lakes with harder, more alkaline water. The two regions have three abundant species in common (*Diaptomus minutus, Mesocyclops edax* and *Bosmina longirostris*), and each have several species not encountered in the other (Adirondack: *Diaptomus sanguineus, D. leptopus, Macrocyclops albidus, Daphnia catawba, Acroperus harpae;* Finger Lakes: *Senecella calanoides, Limnocalanus macrurus, Diaptomus sicilis, Daphnia parvula*). Owing to the nature of earlier Adirondack studies, no historical comparisons can be made.

This study indicates that most Adirondack lakes and ponds have a similar zooplankton composition. But there may be some highly unusual lakes where fish or geochemical factors have altered the environment.

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OCCURRENCE OF THE BIGEYE IN LONG ISLAND WATERS[1]

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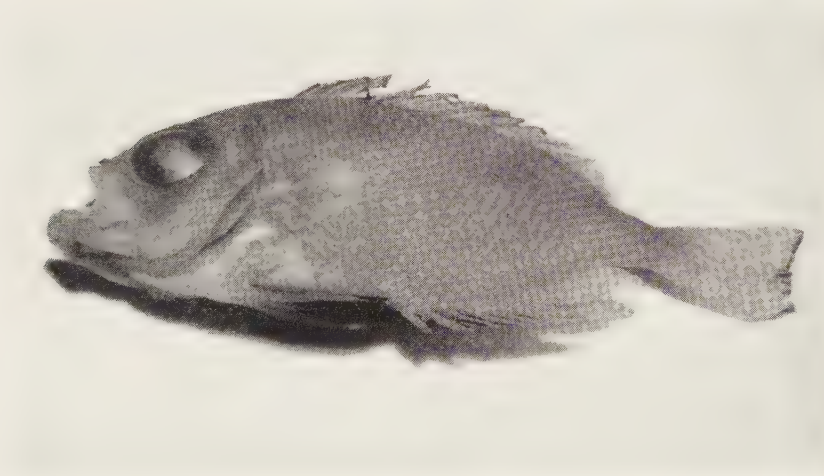
A specimen of the bigeye (*Priacanthus arenatus*), 76 millimeters in total length, was taken on November 8, 1967 in Hempstead Bay about 3 miles east of Jones Inlet. The water temperature was 49.1° F., and the salinity was 29.6‰ The species was not encountered in the extensive collections reported by Alperin and Schaefer (1965). Neither was it reported by Breder (1938), Greeley (1939), Gordon (1949) or Schaefer (1967). Therefore, this appears to be its first recorded occurrence in the south-shore waters of Long Island.

Although the bigeye is not known to have been taken before along the south shore, it has occurred elsewhere in Long Island waters. Latham (1916) listed two



Bigeye (*Priacanthus arenatus*) taken in Hempstead Bay, Long Island.

specimens (3¼ inches and 4 inches in total length) caught in Peconic Bay and stated that a few of about that size were taken each fall. Latham (1964) also reported a specimen taken November 12, 1942 in Peconic Bay and another taken August 3, 1944 at Orient Point.

According to Beebe and Tee Van (1933) and Breder (1948), the bigeye is a West Indian species with a range extending northward to Massachusetts. The northward extension is probably influenced by the Gulf Stream from which, as suggested by Bean (1903), it sometimes moves inshore during the summer and fall. The present specimen was swimming near the surface with obvious difficulty, probably affected by the low water temperature, and was easily caught with a dip net.

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[1] The author wishes to thank Philip Briggs and Richard Schaefer of the New York State Conservation Department for identifying the fish.

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DURATION OF JAW MARKS IN GROWING FINGERLING TROUT[1]

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Fish of a number of species have been sucessfully marked with dyes by injection, immersion or feeding (Kelly, 1967a). Injection by needle or gun appears to be the most practical technique, forming durable, non-mutilating marks on jaws, cheeks and other areas of the body. Several dyes have been used successfully, one of the best with respect to ease of marking, lack of toxicity, and durability being National Fast Blue 8GXM[2]. Durability of marks appears to be correlated with growth; fast growing fish lose their marks more quickly than slow growers which may retain marks for years.

It appears that the size of fish marked and the marking site may also affect mark duration. Jaw marks on all trout marked with National Fast Blue 8GXM when they averaged 7 inches in length lasted until a weight increase of 200 per cent was reached. However, smaller brook trout (*Salvelinus fontinalis*), averaging only 4.5 inches in length when jaw marked, retained all marks after a weight increase of 375 per cent (Kelly, 1967b). It was stated that trout less than 5 inches long cannot be conveniently jaw marked although the smallest fish so marked was only 3.75 inches long (Kelly, 1967a). Very small brown trout (*Salmo trutta*) were successfully injected in the cheek (Kelly, 1967c). These fish averaged only 1.8 inches in length, and all retained their marks through an average weight gain of well over 700 per cent. Mortality due to massive injections of dye was approximately 25 per cent.

An additional test involving jaw marking with the same dye strengthened the conclusion that small trout retain their marks over a greater relative gain in

Table 1. Retention of Jaw Marks by Brown Trout Fingerlings Injected with National Fast Blue 8GXM.

Months after injection	Number of fish		Length (inches)		Weight		Quality of mark
	Marked	Retaining mark	Average	Range	Average (grams)	Gain (per cent)	
0	46	46	3.4	2.7–4.5	7.3	..	All excellent
3	39	39	4.6	3.5–6.0	18.4	150	One poor; others excellent
5	37	37	5.9	4.7–7.7	43.0	490	One extinct; others poor to excellent
7	37	10	7.2	5.5–8.7	83.0	1,040	Poor

weight than do large trout. During this test, injections were easily made on fish as small as 2.7 inches long and without the degree of mortality associated with cheek marking; it is not possible to overinject the thin tissue overlying the jaw.

A total of 46 brown trout averaging 3.4 inches in length were injected in both jaws with a 6.1 per cent solution of dye, using a ½-inch #27 needle. The fish were held at 55° F. with an equal number of controls and were fed dry

[1]A contribution of Federal Aid in Fish and Wildlife Restoration Project F-9-R.
[2]Allied Chemical Company.

fish pellets. At the end of 3 months the average weight gain was 150 per cent, and all marks were excellent (Table 1). At 5 months the average weight gain was 490 per cent; one jaw mark was extinct but the others ranged from poor to excellent. At 7 months the average weight gain was 1,040 per cent, and most of the marks were extinct.

Apparently large trout lose such marks after less relative gain in weight than do small trout. Present information indicates that most fish will retain their marks as follows: cheek-marked fish averaging 1.8 inches in length when marked, for a weight gain of over 700 per cent; jaw-marked fish averaging 3.4 and 4.5 inches in length, for weight gains of over 500 and 375 per cent, respectively; jaw-marked trout about 7 inches in length, for a weight gain of more than 200 per cent.

Jaw injection marking is practical on trout as small as 2.5 inches long, while cheek marks can be made on fish only 1.5 inches long. Cheek marking, however, causes some mortality.

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The work reported here was strictly a laboratory study. A drug or chemical may not be used on fish that may later be consumed as food unless such drug or chemical has been approved by the Federal Drug Administration.—Editor

NOTES ON THE SURFACING OF FISH DUE TO CHEMICAL ACTION[1]

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Many of the derivatives of d-lysergic acid cause surfacing in some species of fish (Abramson *et al.*, 1961, 1963; Loeb, 1962; Loeb *et al.*, 1965). D-lysergic acid is a naturally occurring product derived from an ergot fungus that grows on rye. From it are synthesized compounds, such as lysergic acid diethylamide (LSD-25), many of which not only cause fish to surface, but are also toxic in hallucinatory and other ways to other animals. Of 48 such ergot compounds tested, 36 produced surfacing in a number of species of fish, although some species could not be made to surface by any derivative. The compounds were effective over a wide range of temperature and pH, varied according to concentration, and were rapidly changed by ultraviolet light. Fish appeared to develop an immunity or to adjust to their chemical action. The derivatives of d-lysergic acid possess in common the indole ring system and are often referred to as indoles. But, since not all of them were effective, other factors must be involved.

The work described all pertained to freshwater fish in fresh water. One additional test, however, was carried out on mummichogs (*Fundulus heteroclitus*) and striped killifish (*F. majalis*) in fresh water, and in brackish water with a salt concentration of 0.85 per cent. At a concentration of 0.25 ppm N-isopropyl d-lysergic acid amide, acid maleate caused several species of freshwater fish to surface (Loeb *et al.*, 1965) and at 2 ppm the reaction occurred within an hour, but at 5 ppm this derivative did not affect the specimens of *Fundulus* in either brackish or fresh water over a period of 21 hours. Accordingly, it was concluded that these species cannot be brought to the surface by this compound.

The ergot indoles appear to cause surfacing by affecting the air bladder; surfaced fish often float when not moving, indicating distention. Freshwater fish without an air bladder could not be made to surface. However, this was also true of several species, including those of *Fundulus* that were tested, which do possess an air bladder, showing that surfacing must be caused by a combination of factors. The ergot indoles have not been tested on other species of salt-water fish; the species of *Fundulus* used were chosen because they could adjust to both salt and fresh water.

The ergot indoles have not been tested in the field because of their expense and hallucinatory properties. It is doubtful whether they could be of practical use unless one possessing low toxic properties and surfacing action could be developed; the group is variable in causing both hallucinations and surfacing.

Movement of fish in positive (rather than random) directions by any means has great practical implications for commercial fisheries and for the study of sport fisheries. The surface application of copper sulfate in low concentrations to double net catches in lakes is an example of such chemical manipulation (Tompkins and Bridges, 1958). The increase in efficiency greatly reduced both time and cost. Copper sulfate caused irritation and increased movement of fish, but there is need for other chemicals with other modes of action, both general and selective.

Preliminary tests indicate that non-ergot indoles and other compounds may cause surfacing, at least in the laboratory. Two of six non-ergot indoles tested, namely, 2, 3-benzopyrrole and indole 2-carbohydrazine, were negative at concentrations of 10 and 25 ppm, respectively. The first caused irritability, movement and death, while the second produced no symptoms.

Four indoles induced surfacing in golden shiners (*Notemigonus crysoleucas*) and some development of immunity or adjustment to the compounds: 6-hydroxy-N-dimethytryptamine caused surfacing at 8 ppm, but weakly at best; (DL)-alpha-methyl-tryptamine methanesulfonate was effective in a few hours at 8 ppm with possible development of immunity at 7 days; 3-dimethylaminoethylindole hydrobromide was effective in 5 hours at 10 ppm with development of immunity at 6 days; and 4-methyl-alpha-methyltryptamine was effective at 4 ppm in a few hours with development of immunity in 3 to 4 days. The latter compound was the most effective. Tests were run at 72° F. in tall graduates and low aquaria, and there was some indication that the shape of the container might influence results.

[1]A contribution of Federal Aid in Fish and Wildlife Restoration Project F-9-R.

Seven other compounds were tested in the laboratory and two caused surfacing. Those that did not were acetone at 16,000 ppm, copper sulfate at 3 ppm, potassium permanganate at 6 ppm, rotenone at 1 ppm and antimycin A (Walker *et. al.*, 1964) at 10 ppb. Rotenone has caused mortality and surfacing of some fish at times in the field, especially at high temperatures. Antimycin A may cause some surfacing under field conditions. In one test, however, fish were found in the mud, on the bottom and at the surface (Loeb, 1964).

Two compounds caused surfacing in a manner different than that associated with non-ergot indoles. One of these, 4'-iodo-3-nitrosalicylanilide, produced surfacing in conjunction with mortality at 25 ppb. The other, ordinary table salt, had no effect at a concentration of 1 per cent but caused surfacing (possibly due to change in specific gravity) during a number of tests at concentrations of 1.5 and 2 per cent, and in conjunction with mortality. Not all individual fish were brought to the top. Sublethal concentrations of the non-ergot indoles, however, induce surfacing of all individuals of a susceptible species and may result in immunity.

Additional studies should involve large samples of fish and control of variables. Since results often vary between laboratory and field, tests under field conditions would also be needed.

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The work reported here was strictly a laboratory study. A drug or chemical may not be used on fish that may latter be consumed as food unless such drug or chemical has been approved by the Federal Drug Administration. Also, in New York State, no drug or chemical may be used for fish control purposes in the field without obtaining a Water Resources Commission permit from the State Conservation Department. Permits will be issued only for those drugs and chemicals that have been Federally certified for such use.—Editor

EYELESSNESS DUE TO CANNIBALISM IN A POPULATION OF STUNTED BROWN TROUT[1]

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Cannibalism is common among fish. For example, young muskalonge (*Esox masquinongy*) and walleyes (*Stizostedion vitreum*) are cannibalistic in hatcheries, while young tropical fish are often eaten by adults. Phillips *et al.* (1952) produced evidence that smaller brown trout (*Salmo trutta*) were eaten by larger fish in hatchery troughs; interestingly, cannibalism did not occur in all troughs. Also, Phillips *et al.* (1960) stated that grading of fish reduced cannibalism. In these examples, the entire fish was eaten.

Cannibalism need not result in complete ingestion of one fish by another. Here it is taken to mean any consumption of attached tissue of one fish by another of the same species. On numerous occasions, in large aquaria, yearling brown trout have been observed pecking at each others' epidermis, tearing at open fleshy areas of both living and dead fish, eating fragments or swallowing some fish whole. All of these activities are cannibalism, and it is assumed that due to various circumstances only certain fish in the population fall victim.

Hunger is undoubtedly a factor in such cases of cannibalism, but it alone does not seem to be a sufficient explanation in the light of recent investigations of conflict among both vertebrates and invertebrates (e.g., Ewing, 1966; Barnnet, 1967). Detailed observation and experimentation with fish might reveal cannibalistic activity patterns related to space, crowding, territoriality, sex, size, personality and so on. From such data methods for the mass raising of predatory fish beyond the fry stage might be developed. This would be a major step in fish farming.

Eyelessness, which appears to be a product of cannibalism, has been reported in lake trout (*Salvelinus namaycush*). In hatcheries the condition is most often discovered when the fish are being examined as large fingerlings or yearlings. Only one eye is usually missing, and the conjecture is that eye gouging is associated with underfeeding and heavy population density. It has been suggested, also, that both iodine deficiency and popeye or exopthalmia may contribute to the condition.

A population of brown trout in which eyelessness occurred was followed for nearly a year at the Fish Laboratory at Livingston Manor (N.Y.). Four to five thousand unsorted fish running 450 to the pound (about 1 gram each) were placed in a 550-gallon fiberglass tank having dimensions of 8 x 8 x 3 feet. Temperature of the soft spring water was a constant 47° F. Flow was at the rate of several gallons per minute, and the tank water was replaced 10 times daily. Whether soluble waste products accumulated to any great extent is unknown. Solid waste products plus mutilated fish often piled up in certain areas. Abundant oxygen was supplied by the inflow and an air hose. The fish were fed pelleted food only. The tank was well lighted during the day, but dark at night.

The fish were observed for 11 months. When first placed in the tank there was no obvious evidence of abnormality. During the first 7 months the population was reduced by at least 85 per cent. Some 400 fish were removed for experimental use, but some 3,500 others died in the tank. Most of the dead fish were eyeless, and often the entrails and portions of the musculature were missing. However, the population was not actively observed until it was noticed that a number of swimming fish were missing an eye.

At the end of 7 months, the stunted surviving fish were weighed, measured, counted and examined for evidence of eyelessness (Table 1). Of 673 fish, 36 or approximately 5 per cent were missing an eye. Of these, 22 were missing the

[1]A contribution of Federal Aid in Fish and Wildlife Restoration Project F-9-R. The original lot of fish were held for dye marking and other experiments, and the observations described were made incidentally. Acknowledgments are due to Earl Stiles, supervising aquatic biologist, and Donald Longacre, senior hatchery foreman, for information concerning eyelessness in lake trout, and to Richard Dumas, fish pathologist, who examined the brown trout for evidence of disease. All three are with the New York State Conservation Department.

right eye and 14 the left eye. The normal fish were larger than the eyeless ones. Since the fish were obviously suffering from malnutrition (feeding was cursory) as evidenced by frayed, diseased-looking fins, several were examined pathologically. There was no evidence of active disease.

Among the eyeless fish, the eye sockets of 17 were healed, and those of 19 were raw, often with the end of the optic nerve protruding. The rate of survival of eyeless fish was obviously low since thousands had been removed dead; a few were able to survive long enough for healing to take place. None of the living fish was missing both eyes, an indication that such loss quickly led to death. But many dead fish were without both eyes.

One fish, missing an eye, was held in a separate tank for a month. During a period of 3 weeks the epithelium, which contained chromatophores, completely covered the raw eye socket. Pathological examination indicated that eye loss was due to mechanical removal and not disease.

After the initial 7-month interval, behavior patterns were observed. The fish exhibited attack and defense postures and probable territoriality, and some succumbed to this regimen. The general mass of fish engaged in random movement, probably because the environment contained little in the way of sheltered niches. A few normal fish maintained territories of about a cubic foot, being attacked or attacking a dozen times each in a 10-minute period, but always returning to the same area and alertly guarding it. The duration of such activity was not measured, but maintenance of territory must have been difficult in the face of continuous pressure from great numbers of fish. Possibly, territories were constantly changing and possessed by only a few fish at a time.

A one-eyed fish was observed under violent attack as well as deliberately attacking other fish over a 15-minute period. This fish also picked specks of material off the bottom of the tank and had obviously made an adjustment to the loss of an eye.

One fish with a raw eye socket was observed in the last stages of social defeat before removal of the second eye and death. It was first seen in a corner of the tank and in contact with the bottom. During 1.5 hours the fish was at-

Table 1. Changes in Condition of a Crowded Population of Brown Trout Over a Period of 11 Months*

Item	Time	
	End of 7 months	End of 11 months
Total surviving	673	529
Normal fish		
Number	637	510
Per cent	94.7	96.4
Average length (inches)	3.2	4.2
Range in length	2.7–3.7	3.0–5.3
Average weight (grams)	6.9	12.1
Eyeless fish		
Number	36	19
Per cent	5.3	3.6
Average length (inches)	2.9	4.0
Range in length	2.5–3.5	3.4–4.4
Average weight (grams)	6.2	11.3

* Population at start consisted of 4,000 to 5,000 fish averaging 1 gram in weight.

tacked 45 times, 13 against the good eye, 6 against the socket, 10 against the head and 16 against the body. It did not engage in evasive tactics, but was thoroughly sick and defeated. The attacks, made by many individuals, were digging, biting attacks and not nips. During the following half hour, the fish was not observed; its other eye was removed during this period, and the fish, when next seen, was being battered about by hordes of fish. It died in several hours.

At the end of 11 months, the fish numbered 529; 144 had died during the final 4-month period, largely due to cannibalism. Nineteen (3.6 per cent) were missing an eye (10 left and 9 right), but all of the sockets had healed over completely, showing that these eyeless fish had adjusted socially to their condition. The fish had grown to some extent, as shown in Table 1. Again, the eyeless fish were smaller than the normal fish.

Cannibalism continued after the 11 month examination with a mortality rate of about a fish a day, despite good feeding. Evidently the habit of cannibalism was ingrained, or conditions made it inevitable and normal. Detailed observations, however, were concluded.

The causes of cannibalism among these fish may have been hunger, crowding or other social situations, or both. Probably it was initiated by hunger. However, there is rough evidence that increased space led to increased growth and to a loss of cannibalistic activity.

When the fish were first placed in the 550-gallon tank they were in good condition. During the first 7 months they were fed only occasionally, and at the end of that time they were in poor condition and had become cannibalistic. Just before the 7-month examination, 80 were placed in a 350-gallon tank. For 4 months, or until the 11-month examination, these fish and those remaining in the 550-gallon tank were fed five days a week, and as much as they would eat. The smaller group prospered, grew at a much faster rate and lost their cannibalism. The larger group improved in condition, grew at a lesser rate and maintained their cannibalistic activity. Evidently overcrowding was an accompanying cause of cannibalism and also retarded growth.

Well defined social relationships, often including territoriality, and fighting, were earlier described for fish (Breder and Halpern, 1946; Greenberg, 1947; Noble and Curtis, 1939). Brown (1946) described a peck order in brown trout which retarded the growth of smaller fish.

Similar activity, often resulting in death, has been demonstrated for the cockroach (*Nauphoeta cinerea*) by Ewing (1967). Obviously, individual social actions are not limited to vertebrates. A description of social activity in rats (Barnett, 1967) divides the males in a colony into three types: alphas, betas and omegas. The alphas are dominent, the betas adapted to a subordinate role and the omegas doomed.

In rats, cockroaches and certain fish, death of omega-type individuals often ensues after attack, but without external evidence of injury. Whether cannibalism in young brown trout began with attacks on omegas is unknown, but it is reasonable to believe that a measurable social structure was present. It does seem probable that overcrowding of individuals causes continuous effort to maintain social structure with resulting dissipation of energy, poor condition and growth, and mortality. This may partially explain stunting in both aquaria and open waters and also such conditions as loss of young salmon, for example, from crowded streams.

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SOME OBSERVATIONS CONCERNING FISH FOUND ON THE MONTEZUMA NATIONAL WILDLIFE REFUGE

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The Montezuma National Wildlife Refuge is located at the northern end of Cayuga Lake in central New York. It adjoins the Seneca River and Barge Canal and comprises a main pool of about 1,200 acres and several smaller water units. All of the pools are shallow impoundments and are managed primarily as resting and feeding areas for both spring and fall migrating waterfowl and secondarily as nesting areas for various species of waterfowl.

During the spring, summer and fall of 1966 the author studied the association of macroinvertebrates with 12 species of submerged aquatic plants on the Refuge. Also, fish collections were made at least once a week during the 7-month study period. These collections were made at different locations throughout the main pool complex using a 3 x 5-foot common sense minnow seine operated either by wading or from a canoe. The observations concerning fish are summarized here.

Eight species were represented in the collections: northern pike (*Esox lucius*), brown bullhead (*Ictalurus nebulosus*), carp (*Cyprinus carpio*), central mudminnow (*Umbra limi*), golden shiner (*Notemigonus crysoleucus*), banded killifish (*Fundulus diaphanus*), brook stickleback (*Eucalia inconstans*) and pumpkinseed (*Lepomis gibbosus*). Several others had been reported from the Refuge in previous years, but they were always uncommon and their occurrence probably resulted from spring flooding from the Seneca River.

Carp were the most abundant fish on the Refuge. Pike were extremely rare, and no small pike were encountered, indicating that successful reproduction did not occur. Large bullheads were also rare, but young of the year were abundant. The smaller species were common. Specimens of 12 inches or more in length involved only pike, bullheads and carp.

The larger pike and bullheads presumably entered the Refuge via spring floodwaters. Most, if not all, of them succumbed during the second week of July. Unfavorable water temperatures (as high as 87° F.), turbidity (as high as 160 Hellige units) and low concentration of dissolved oxygen (less than 3.0 ppm) undoubtedly were important factors. Moore (1942) reported that many fish species have difficulty tolerating concentrations of dissolved oxygen lower than those recorded here.

Many authors have documented the detrimental effects of carp on aquatic plants. In a recent study King and Hunt (1967) found that "Carp significantly affected the total abundance of vegetation . . ." They destroy the vegetation by uprooting it, and their activities increase turbidity to such an extent that many plants cannot tolerate the accompanying environmental changes. Aquatic plants not only are themselves a major source of food for waterfowl, but they support populations of invertebrates which are also eaten. When the plants disappear, so do the invertebrates. Although the carp is omnivorous and so, theoretically, competes directly with waterfowl for food, its indirect effects are more important.

The golden shiner, bullhead, mudminnow, banded killifish and brook stickleback are also omnivorous, but animal material is probably their principal food. Pike and pumpkinseed are primarily carnivorous.

On a marsh such as Montezuma, which is managed for both migrating and nesting waterfowl, an abundant and diverse supply of waterfowl food is desirable from early spring to late fall. In addition to the detrimental effect of carp on aquatic vegetation, they and the other species all consume large numbers of aquatic insects, molluscans and crustaceans. These invertebrates are an important source of protein, especially for egg-laying hens, ducklings and molting adult waterfowl. But whether or not a significant degree of competition for this animal food existed at the time these observations were made is not known.

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